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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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No. 861.

THE ARTIFICIAL PRESERVATION OF RAILROAD TIES BY THE USE OF ZINC CHLORIDE.

By WALTER W. CURTIS, M. Am. Soc. C. E.

PRESENTED MAY 17TH, 1899.

WITH DISCUSSION.

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It is hoped that this paper may to some extent add to the knowledge on the subject and place in accessible form that which has already existed for those who knew where to find it.

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Ties in General.

Any investigation of the timber resources of the country is bound to be exceedingly disappointing, on account of the impossibility of securing any complete, or even correct partial data.

The Government, through the Department of Forestry, has investigated the subject, and has collected much information as to the supply, the consumption, the characteristics of the material and the best methods of using and economizing American timbers. With reference to the special subject of railroad ties, the Department, in 1882 and 1883, by means of circulars, collected data from 283 different corporations, representing over 70 000 miles of track. This data covered the size and number of ties used per mile, the kinds of timber used, its durability and cost, with general information as to the sources of supply, etc. In 1886 inquiries covering somewhat similar ground, resulted in replies from 35 representative corporations, operating 46 000 miles of track. The first indicated the average life of ties to be as follows: White and burr oak 7 years, cypress 9 years, redwood and cedar 11 years, and for other woods generally 5 years. In the later report it is stated:

"While no general rule can be laid down as to the lasting quality of timber imbedded under the track and used in bridges and trestle work, subject, as it is, to the endless varieties of conditions of soil and climate in different sections of the country, nevertheless, it may be safely assumed that 7 years is the limit of the average usefulness of ties of the best kinds of hard wood, and 4 years for the soft woods."

The 46 000 miles of road, covered by the 1886 report, used in renewals, the preceding year, 16 700 000 ties, at an average cost of 35.6 cents each. "The average number of new ties required annually for each mile, to replace decayed ones, is 365; the average duration of ties, 7.2 years."

In the report on metal ties and the preservative processes for wooden ties, prepared by E. E. R. Tratman, Assoc. M. Am. Soc. C. E., under the direction of Mr. B. E. Fernow, Chief of the Division of Forestry, and issued in 1894 as Bulletin No. 9, the situation is summarized thus:

"Briefly recapitulating statistics as given in the previous bulletins, it may be stated, that with an average of 2 500 ties per mile, the 230 000 miles of track, including second, third, fourth and side tracks, represent 575 000 000 ties in service. Renewals require an-

nually upwards of 75 000 000 ties" (corresponding to 7⅓ years of life) "new construction 13 000 000 ties, or the total annual consumption in round numbers of 90 000 000 ties, equal to 450 000 000 cu. ft. of forest-grown material, to which some 60 000 000 cu. ft. for bridges and trestle work must be added, making the total consumption for railway purposes exceed 500 000 000 cu. ft. This requires the annual culling of the best timber from probably more than 1 000 000 acres, and the annual product of at least 50 000 000 acres in good condition, or more than 10% of the present forest area of the United States reserved for this one use alone."

Benjamin Reece, M. Am. Soc. C. E., demonstrates* conclusively the very largely increased relative importance of tie renewals as compared with rail renewals; the expenditure for ties on various roads having increased relatively to rails in the years 1880 and 1890 nearly 300 per cent. Most of this remarkable increase was undoubtedly due to the decreased cost of rails per ton; and the data are lacking in Mr. Reece's paper to determine how much, if any, is properly attributable to increased cost per tie or to decreased life. The increased importance to the railroads of the expense of tie renewals, however, is not affected, whatever the reason; and the evidence of the urgent need of study and effort to reduce the cost of such renewals is sufficient.

It is difficult to learn much about the history of the ties on many American roads. A rail carries with it the name of its maker, the year made and a guaranteed life. The tie is simply a stick, looking much like any other, with no marks on it and no record anywhere. The officials know that the first ties were originally laid during a certain year; that perhaps these were largely replaced when new rails were put down at a later date; that some have been renewed each year since; and generally that is all that can be accurately stated. Some roads can do more, and can tell how many ties have been replaced on each section each year; but if an attempt is made to ascertain the average life of a certain kind of tie, or of all kinds in the main track, it will almost invariably result in disappointment. In certain instances there may be particular stretches of road where for special reasons the roadmaster remembers more definitely how many ties have been removed. This is generally where the ties have been remarkably durable, or else short-lived, and, based on that recollection, the life of that particular kind of tie is apt to be given as longer or shorter than a general average would justify.

* "The Increasing Cost of Railway Tie Renewals." *Transactions*, Am. Soc. C. E. Vol. xxvii, p. 640.

The trouble is that there has never been, nor is there now, any generally accepted method of marking ties; and indeed there is no particular advantage in knowing just how long any single untreated tie has been in place. Presumably the best obtainable of the kind are bought, and when they are destroyed more must be purchased. The kind selected has usually been the best obtainable from the adjacent land.

It is hoped that the discussion of this paper will bring out the records of careful determinations of the life of various woods used as ties.

It may be concluded that at present the only information regarding the probable life of ties, free from the very large element of personal opinion, to be secured from American roads generally, is to be obtained by taking the total tie renewals per mile of road per year, averaged over, say, 5-year periods. This will indicate the average number of annual renewals per mile, and whether the average life of the ties is varying. Covering sidings as well as main tracks, however, such information is misleading, as regards the life of a tie in the main line, must be carefully interpreted in the light of the particular conditions for each road, and can be considered as indicative only. To compare one road with another, the conditions must be alike; about the same relative proportion of siding and main track; of hard and soft wood, and of tie-plates used; and the same climatic conditions must obtain. As indicative of the latter, J. F. Wallace, M. Am. Soc. C. E., Assistant Second Vice-President of the Illinois Central Railroad, states that white oak ties on his lines south of the Ohio River have an average life of from 4 to 6 years, depending upon the height of the land where the timber was grown, the season when cut and the kind of ballast.

North of the Ohio, in central and southern Illinois, the average is from 7 to 9 years, and in northern Illinois and Iowa it is from 9 to 12 years.

Through the kindness of the officers of some roads and from an examination of the annual reports of others, the author has secured certain data on renewals, which are of sufficient interest to warrant preservation. Mr. Wallace states:

"The average number of ties used each year on the Illinois Central Railroad for the past 18 years has been, approximately, 300 to the mile. The annual number used per mile, however, has varied from as low as 221 to as high as 434. I estimate it will require an average

of 350 ties per mile per annum, taking our line as a whole, to keep up normal repairs, on the basis of 3 000 ties per mile of track."

Generally speaking, white oak ties are used north of Memphis, and cypress ties south thereof.

E. A. Handy,* M. Am. Soc. C. E., has given the annual renewals per mile for his road for the past 15 years, showing a variation from 174 to 359 per mile. The average per year for the 5 years from 1883 to 1887 is 310; for the 5 years from 1888 to 1892, 317; from 1893 to 1897, 209. The only explanation obtainable for this very remarkable decrease is the reported construction of a large amount of second track in 1892, 1893 and 1894, resulting in increased mileage without increased tie renewals. However, as the total trackage of all kinds in 1891 was 2 512 miles, and in 1897 was 2 651 miles (an increase between these years of less than 6%), the one-third decrease in renewals is hardly accounted for. The extensive preparations made prior to 1893 for the demands of traffic during the Exposition at Chicago may have had something to do with it. As evidence that it was not due solely to extreme economy during the poor years just past, it may be stated that the renewals for 1897, while in excess of the four previous years, were only 245 per mile. White oak ties are used principally.

The annual reports of the Chicago and Northwestern Railroad give the average annual renewals for the years 1883 to 1887 as 206 (not exact, as the length of side-tracks for 4 years was estimated), 1888 to 1892, 216; 1893 to 1897, 207. During these years the track mileage increased from 4 100 to 7 057, the increases being made by yearly additions of reasonable uniformity. So far as an indication of the real average life of ties is concerned, the figures are deceptive.

An average renewal of 210 ties corresponds to a life of 13⅓ years, assuming 2 800 ties to the mile, and, on the mileage of 1897, to a total number of ties renewed of 1 481 970. If the 13 years in fact represented the average life, and no allowance was necessary for the ties destroyed earlier on the extensions, before the average life had been reached, this number of renewals should correspond approximately to that of the mileage in 1884, which was about 4 400. As this gives a renewal per mile of 337 ties instead of the actual 210, it is evident that this latter figure is deceptive and is due to the rapid increase in the length of the road.

* Chief Engineer of the Lake Shore and Michigan Southern Railroad.

Further trial computations indicate to the author that the probable average life is about 10 years, corresponding to an average renewal rate of about 280 ties per year.

Mr. J. E. Blunt, Chief Engineer, states that the ties in all their principal main lines are white oak, now of a decidedly poorer quality than formerly used, from which they get 8 to 9 years' life. The balance of their ties are cedar, giving 12 to 14 years' service. The ties, per mile, average about 2 700.

R. Montfort, M. Am. Soc. C. E., has kindly furnished statistics for the Louisville and Nashville Railroad, from which the following results have been deduced:

Average renewals per mile for 15 years prior to 1898	360
" " " " 10 " " "	342
" " " " 7 " " "	334
" " " for the year 1896–97	398
" " " " " 1897–98 as recommended	375

Noting that the figures for the renewals for the 10 and 15-year periods include only those divisions which have been built that length of time, on which the amount of new track laid is presumably quite small, it is fair to assume the average life of ties on this road to be about 8 years.

On the Chicago, Milwaukee and St. Paul Railroad the record, prior to 1889, was not readily obtainable. Beginning with that year's annual report the renewals each year to 1897 were, 280, 210, 204, 228, 245, 245, 266, 262 and 242. The average of these is 243, corresponding to a life of about 11 years, the average ties in use per mile of all tracks being about 2 700. During these years the mileage increased from 6 810 to 7 747, an amount probably not sufficient to affect greatly the apparent life of the ties. At present about 50% of new ties purchased are white oak, and about 45% white cedar. In past years a considerably larger percentage has been white oak.

Through Thomas Rodd, M. Am. Soc. C. E., the statistics for the Pennsylvania Railroad, West of Pittsburg, have been furnished by Mr. Charles Watts, General Superintendent. The average life of various woods used for ties is:

Oak, 9.2 years; hackberry, 4 years; tamarack, 5 years; cedar, wild cherry, honey locust and black walnut, 8 years.

The method of determining these periods is not stated. The tie renewals since 1883 have varied from 168 to 363. The average by 5-year intervals is: 1883 to 1887, 236; 1888 to 1892, 289; 1893 to 1897, 212. During these years the cost of ties has increased about 10%, and the quality has deteriorated. The length of haul in the woods has increased an average of 6 miles for the system, indicating the exhaustion of the nearer lands.

Mr. J. B. Berry has furnished data for the Fremont, Elkhorn and Missouri Valley Railroad, of which road he was Chief Engineer until quite recently.

The figures do not extend back beyond 1893, but they are remarkable, both for their extreme smallness and the excellent system indicated. The entire renewals for 1 344 miles of main track, none built later than 1888, and some in 1868, were 470 per mile for the years 1893 to 1898, inclusive, or less than 80 per mile per year. The renewals figured for 1898 were those recommended to be used. This very small number is due to various causes: The location of the line in an extremely dry section, the rigid economy required during the period of commercial depression, the light traffic and the use of large numbers of cedar ties under their most favorable conditions. A considerable part, however, is undoubtedly due to Mr. Berry's systematic and constant inspection of the ties, as requisitioned for and, when removed from the track, as destroyed. Each year tables similar to those shown in Forms A and B have been prepared, giving the data for every portion of the road.

FORM A.

Location.	Miles of main track.	Year road built.	Average number of ties per mile of main track.	Assumed average life of ties in years.	Making average per mile per year for main track.	Number ties requested per mile for 1898 main track.

FORM B.

Location.	Miles of main track.	Year road built.	Renewals per Mile.					Proposed for 1898.
			1893.	1894.	1895.	1896.	1897.	

All ties removed during the year are piled up and not destroyed until inspected by the Chief Engineer, and to this *post mortem* Mr. Berry attributes most of the credit. Presumably he claims no originality for either the method of tabulating the facts or the final inspection. Mr. Reece, in the paper previously referred to,* states that he inaugurated the same system on the Lake Shore and Michigan Southern Railroad with great benefit; but, as the author has found sufficient evidence of the need of such systematic care, he feels justified in presenting Mr. Berry's method to the Society.

None of the roads mentioned has used treated ties more than experimentally, if at all. The figures given for renewals, excepting in the last instance, are per mile of all tracks, both main and sidings, and consequently correspond to a longer life than is obtained in the main track. This accounts for the discrepancy between the life of ties given by the average renewals, and that previously stated by the various roads, as the actual life of particular woods in the main track service. The average annual renewals for the past 15 years, indicating very clearly the climatic effect, are:

Pennsylvania Railroad, West of Pittsburg.....245;
Lake Shore and Michigan Southern.....280;
Chicago and North Western .....280 (corrected for extensions);
Chicago, Milwaukee and St. Paul.....243 (for 9 years only);
Illinois Central. .....300 (350 on basis of 3 000 ties per mile);
Louisville and Nashville..... ...360.

Ties perish by the mechanical destruction of the fibers under the rail; splitting by seasoning and cutting out of fiber by respiking; and by natural decay. In its normal condition, to resist these three influences, a timber is required which shall have sufficient hardness to resist the mechanical injury; a high degree of coherence between fibers; and a sap of such chemical composition as will offer the least encouragement to the development of the fungoid life which destroys the fiber.

The destruction of the fibers under the rail is generally attributed to the cutting and abrading action due to the deflection of the rail and

* *Transactions*, Am. Soc. C. E., Vol. xxvii, p. 640.

tie and the longitudinal movement of the rail as the load passes over it; and the direct compression of the timber is considered as too small to affect it. If a 60-lb. rail has a bearing on the tie of 4½ x 8 ins., or 34 sq. ins., an engine with 30 000 lbs. on an axle would cause a pressure of 441 lbs. per square inch on the tie, making no allowance for distribution by the rail. According to investigations of the Forestry Department of the Government, the pines and cedars, when saturated with water, as the surface of a tie is likely to be at times, have a resistance to a 3% penetration across the grain, of from 400 to 500 lbs., corresponding to the assumed working limit of compression. As the condition of a full bearing on a new tie is decidedly improbable, it is by no means impossible that in such woods, the initial cutting under the rail may be due largely to the direct compression.

The injury by splitting from seasoning can be reduced by covering with ballast a larger part of the ties subject to such action, and that from respiking by carefully plugging all spike holes. As to the general practice regarding plugging, the author is not qualified to speak. He understands that it is generally neglected, but he knows of one road which supplies the section men with turned plugs of seasoned elm; and the instructions are that every hole shall be carefully plugged, whether the spike is redriven into it or not, unless the tie is so decayed as to necessitate removal within a year. The results are reported as being very satisfactory and the slight expense of providing the proper material for such use fully justified.

To secure the best results with any tie, it is necessary that the tree be cut at the proper time, the wood seasoned before being placed in the track, and the roadbed well drained. The necessity for cutting at a particular time has been attributed to various causes: The greater amount of sap, the greater activity of the sap, the change of position of the sap in the tree and the change in the character of the sap at certain seasons, which were consequently to be avoided for cutting. The latest dictum on the subject, as contained in the 10th Bulletin of the United States Forestry Division, and reprinted in Professor J. B. Johnson's "Materials of Construction," is:

"Wood cut in the fall is more durable than that cut in summer, only because the low temperature of the winter season prevents the attack of the fungi, and the wood is thus given a fair chance to dry. Usually, summer-felled wood, on account of the prevalent high

temperature and exposure to sun, checks more than winter-felled wood; and since all season-checks favor the entrance of both moisture and fungus, they facilitate destruction."

Whatever the reason, there seems to be no question but that in the northern part of the United States, timber should be cut in the late fall and winter. The value of seasoning seems also to be undisputed, but the record of experience on the subject is small. That the roadbed should be well drained, to prevent the decay of the ties, is evident; and that the ballast should not cover the ends of the ties, so as to prevent the ready escape of water and the circulation of air around them, is good practice which is frequently ignored.

The immediate cause of the removal of the average tie is dependent upon the character of the timber used, the climatic conditions, the severity of tie inspection, both when purchasing and after service in the track, the character of the roadbed and the amount of traffic. It may be decay or the mechanical destruction under the rail. If it is decay, it may be the general failure of the stick, or local rot under the rail. In any case, it may be concluded that anything which will postpone the decay of the wood, will add to the life of the tie, for where the fibers are injured, rot will find favorable conditions for development, and where the rot has begun, the fibers are reduced in strength and quickly destroyed. With certain woods durability can be secured by mechanical means for preventing the breaking down of the fibers under the rail, as by tie-plates. This is especially true of cedar, cypress and redwood. Woods which are of such texture that they resist decay and mechanical injury equally well for considerable periods, and have consequently been the most satisfactory timber for ties, are unfortunately few; being the white, burr, chestnut, post and rock oaks. With most of the American woods, however, nothing will materially prolong the life of the tie which does not essentially change the condition of the sap. Such change may in itself be sufficient to make a timber perfectly adapted for use as a tie, or it may still be necessary to protect it from mechanical injury; the determining factors being the character of the timber operated on or the process used.

The oaks, which have been in the past and still are in some localities the principal source of the best ties, are rapidly being exhausted. It is an especially favored road which can to-day secure any considerable

supply of good white or burr oak from its own territory, and even then it is the policy to use the oak for but a part of the supply, supplementing it with other and less desirable materials. The report of one of the committees of the Roadmasters' Association, made to the annual meeting held in Denver in September, 1898, may be quoted as indicating the general conviction that the day of the hardwood tie is nearing its close. This report recommended:

"That tie-plates with soft ties be used in preference to hard ties without any plate, when the natural life of the soft tie is equal to or greater than the natural life of the hard tie, cost being equal."

The cedar is being more largely used with and without tie-plates, but any largely increased demand for cedar, due to its adoption generally, would probably cause a rapid increase in cost. It is not a wood which is generally or uniformly distributed throughout the country; and even in Chicago, closely adjacent to the cedar supplies, the increased demand of the last 3 years has advanced the price from 25 cents to 38 cents.

The future supply of ties must undoubtedly come from what are now considered the second-class or even waste woods. These, after chemical treatment, will resist decay for from 10 to 12 years and will generally cost less than the white or burr oaks.

One of the causes which has prevented the more general adoption of preservative methods, has been the low cost of timber, even of the best quality. Notwithstanding the generally admitted fact that the supply of such timber is materially less than it was 10 years ago, in many localities the cost is no greater than it was then; and in some cases it is even less. One of the Western roads, which 10 years ago paid 50 cents each for the white oak ties purchased along its own lines, is now paying for the same tie 45 cents; and, owing to stricter and more thorough inspection, it is getting better timber. However, although this road runs through a magnificent timber country, and purchases all the oak offered for sale on the line, it has been found necessary to supplement the supply by importations from the South at higher prices, and by the increased use of soft woods. This year a larger percentage of soft woods will be used than has been the custom.

One explanation of this shortening of the supply without a corresponding increase in cost may perhaps be that given in one of the Government reports on the subject:

"The agencies employed in supplying the enormous quantities of ties required by the railway system may determine, to a great extent, the amount and price of material offered in the market. In many parts of the country the cutting and hauling of ties to railway stations is performed mostly by farmers to whom this labor is a source of ready cash and employment of spare time. Owing to this mode of supply, an abundance of material is steadily offered, giving railways full control in the selection of the best quality and in the price paid; while by a regulation of the rates of freight they can prevent an undue export to the treeless sections of the country, or check materially the lumber industry of certain localities. In this way prices are kept down and a show of seeming abundance is maintained which does not in the least prove the supply to be adequate, but merely shows that the great number of people engaged in this industry are willing to haul ties to the railway over distances steadily increasing as the timber nearest the lines is cut off. Immense quantities of tie-timber are thus cut down and delivered to the railways at prices below its real value. At the time the leading lines west of the Missouri River were constructed, extensive tracts of white oak timber were laid waste in the Western States. And the same process is going on throughout the white cedar regions of the North, from which immense quantities of ties are thrown on the timber market. These channels of supply, based solely on considerations of monetary profit, will continue to bring to market the forest wealth of many sections of the land, but in many instances and at a time not far distant Nature's bountiful supply will be exhausted, and the reckless system of forest clearing will of necessity be a thing of the past."

This was written 12 years ago and the truth of it is evidenced by the greater scarcity, and, so far as many roads are concerned, practical exhaustion, of the white oak supplies in the northern part of the country.

The constant extensions of railroads into new territory, opening up forests before inaccessible, has had even more to do with the stationary prices. A recent number of a trade publication* says:

"So long as railroad rails rest on wood, so long the white oak tie will be wanted above any other available wood. A large proportion of the mileage of western roads has for many years been laid with this tie and on ties brought from the woods of the three white pine States. But the time has now come when this source of supply is failing rapidly.

"The States of Michigan, Wisconsin and Minnesota to-day furnish probably one white oak tie where 5 years ago they furnished five. With the present rate of cutting these ties in these States, the supply 5

* *The Mississippi Valley Lumberman.*

years hence promises to be insignificant. Four-fifths of the white oak ties now being bought by the roads running through these States are brought from the South. In time the supply will be almost wholly from the South.

"Though the supply of white oak suitable for ties has grown so small in the North, the market value of this tie has remained almost stationary because of the recent influx of the Southern tie. The Omaha, the Soo, the Wisconsin Central and the Milwaukee lines have this year drawn the bulk of their white oak from the South. A reduction in freight rates is in part responsible for this."

Experience with Southern oaks when brought North seems to be somewhat contradictory, but is probably unsatisfactory, while the cost is high. As a consequence, it is believed that the supply of ties generally and very shortly will have to come from the inferior grades of timber, with a corresponding large increase in the number of annual tie renewals, unless it is possible to so treat them at a low cost as to give them a life equal or superior to that now secured from the oaks.

Résumé of Report of 1885.

In 1885 a Committee of this Society, consisting of nine members, presented an exhaustive report on the subject of the preservation of timber; which, with the discussion thereon, participated in by sixteen other members, still stands as the authoritative statement on the subject; and many of the general conclusions of the Committee remain uncontroverted to-day. Very naturally, however, during the past 12 years much has been learned, some of the ideas formerly held have been modified and confirmatory evidence produced as to others.

The conclusions in the report on the preservation of ties were:

"If the exposure is to be that of a railroad tie, creosoting is, doubtless, the most perfect process to use, but in view of the expense, it may be preferable to use a cheaper process, dependent somewhat upon the location.

"With our present knowledge, and as a result of this investigation, we believe Burnettizing (the zinc-chloride process) is the advisable process to use for ties at present in this country."

The facts upon which the conclusion as to the sufficiency of Burnettizing was based were the following:

A street railway in Cambridge, Mass., was laid with spruce stringers and sleepers in 1855. In 1883, 28 years later, the stringers

were all worn out, but the president reported that "many, and, I think, the majority of the sleepers are in good condition to-day."

On the Vermont Central Railroad ties were treated in 1856 to 1860, at which time the plant was abandoned and the entire matter lost sight of until 1879, "when an old side track was removed, which had not been in use for several years, and which was nearly covered with earth and grass; still the hemlock ties were then found to be nearly sound" after over 20 years.

"The reasons for abandoning the Burnettizing works upon this road would seem to be that the officers in charge at that time lost faith in the theory, and, as it was an experiment, they did not learn of its value until recently discovered in the manner referred to."

In a wharf and in a street railway in Boston, Mass., spruce plank and track stringers which were Burnettized in 1857 were sound in 1872, or 15 years afterward.

On the Chicago, Rock Island and Pacific Railroad eight spans of Howe-truss bridges built in 1860 were still in use and in fair condition in 1882. On this road 2 000 ties of hemlock, pine, tamarack and cedar were laid in 1866. In 1882 about 75% of the hemlock was still in the track and good for several years longer; the pine and cedar ties had all been removed sometime during the 15 years—the tamarack lasting about as long as the hemlock.

On the Boston and Albany Railroad a 100-ft. bridge, built in Boston by the late E. S. Philbrick, M. Am. Soc. C. E., was provided with green spruce Burnettized ties in 1860 which lasted 9 years. They were replaced by untreated pine, lasting 6 years, and these were replaced by untreated chestnut, lasting 7 years.

Untreated spruce is stated by Mr. Philbrick to have a life of 4 to 5 years.

On the Lehigh and Susquehanna Railroad, L. L. Buck, M. Am. Soc. C. E., reported in 1883 that he had examined Burnettized maple, beech and hemlock ties laid in 1867–68 which had "resisted decay almost perfectly. Most of the treated ties appeared good for 7 or 8 years longer."

This represents the American experience in 1885 favorable to zinc chloride as a tie preservative. There were, in addition, the results of 30 years of German experience, which can be summarized from Councillor Funk's paper in the report as follows: In 1880, out of 60 000 000

ties laid on the German and Austro-Hungarian railroads, about 25 000 000 were impregnated, the majority with zinc.

"As the experience of those railroads that have for from 25 to 26 years impregnated their ties with chloride of zinc under pressure, after steaming and abstracting the sap, has been very satisfactory, and as this system costs only one-half to one-third as much as impregnation with creosote or corrosive sublimate, the majority of roads have adopted the chloride of zinc process.

"The average life of ties impregnated in a rational manner with creosote or chloride of zinc under a powerful pressure reaches:

"For oak ties	19.5 years.
" fir ties	14 to 16 years.
" pine ties	8 " 10 "
" beech ties	15 " 18 "

"The results of impregnation of chloride of zinc and creosote are about equal. But, as the impregnation with creosote costs about three times as much as with chloride of zinc, a majority of the German railroads have gone over to the latter."

In addition to this favorable evidence, there was some which was unfavorable. In 1861 the Erie Railroad built a plant at Owego, N. Y., in which plank and bridge timbers, as well as a few experimental ties, were treated. The results were unsatisfactory, the large timbers, in 8 or 9 years, having decayed at the center, leaving a hard crust on the outside. In the opinion of the Committee, the reasons for the unfavorable results were: The original imperfections in the "Bethel process," it being attempted to extract the moisture (before injection) by the vacuum alone, without preliminary steaming; the selection of bridge timbers which are less adapted to the treatment than ties; operating on entirely unseasoned timber, and, perhaps, the use of insufficient pressure. Referring to the use of green timber:

"As a confirmation of this view, it may be mentioned that, while the bridge timber did not last well, several sets of switch ties, which had been cut about eight months and seasoned, were Burnettized at Owego for the road department of the Erie Railway, and laid in its tracks, with the result that 9 years afterward they did not show a particle of decay. These ties have been lost sight of since, but your committee has in its possession an oak tie, one of a lot of two car loads, seasoned and Burnettized at Owego, which lay in the track at Susquehanna Station for 17 years, and is almost perfectly sound to-day."

The Philadelphia, Wilmington and Baltimore Railroad and the Philadelphia and Reading Railroad built works in 1863 and 1867. The

results were satisfactory as regards decay, but the strength of the timber was so injured that the ties broke in the track.

"The explanation is that the solution was too strong, and the surplus zinc probably crystallized in the sap ducts of the timber, burst some of them asunder, and so made the wood brittle. On the Philadelphia, Wilmington and Baltimore Railroad a solution was used probably 5 or 6% strong, and on the Philadelphia and Reading Railroad the solution was 3¾% strong, while experience in Germany has thoroughly established the fact that for railroad ties the solution should not be over 2% strong, and 1.91% is considered the standard."

The present German practice, as to strength of solution, will be given later. There is no evidence known to the author to confirm the supposition that the surplus zinc contained in solutions of the strength mentioned has ever crystallized in the ducts and injured the fiber. It is probably simply a conclusion based upon an idea.

In the consideration of this record in the United States it is necessary to remember that while the use of zinc chloride as a preservative of wood was patented in 1838, the Bethel process of securing the saturation of the timber by pressure preceeded by partial vacuum was invented in 1840; and an attempt to apply the treatment was made here as early as 1850. The work for the next 20 years was largely experimental. Everything had to be learned as to the proper methods of treatment, the process perfected, and the best materials to work upon ascertained. Timber was then so cheap and plentiful in the United States as to leave but small incentive to devising means of economizing it. That the results of treatment were so largely favorable and the probable causes of failure so evident, is remarkable. The record of the hemlock and tamarack ties on the Rock Island road is difficult to account for, in the light of later experience. After 15 years' service, 75% were reported as still in the track. As will be seen later, the more recent hemlock ties on this road show a shorter average life, and it must be that the previous statement was in error, or the treatment the ties received before and after they were put into the track was more favorable than that of later years.

An endeavor has been made to learn the facts as to the method of treatment followed with these ties, but the only person accessible who had personal relations with the work in 1866 disclaims all recollection of the details and no written records were kept. The author has been told, however, that these ties were cut in December, cross-piled to

season until the following October, then treated and allowed to dry before they were placed in the track. If this is true, their record is probably fully accounted for, and can be duplicated if the same conditions are supplied.

Councillor Funk's statement that the results of impregnation with creosote and with chloride of zinc were about equal, is evidently in error. In the "Organ of the Progress of Railroads," series 1897, published in Wiesbaden, there is a table in which the average duration of various ties on the German railroads is given for the zinc treatment and also with tar oil (creosoted). These are:

Oak ties,	treated with	zinc chloride,	15	years; with	tar oil	24	years.
Beech	"	"	9	"	"	30	"
Pine	"	"	12	"	"	20	"

Progress Since 1885.

At the time of the report to the Society, three plants treating timber with zinc chloride were in operation in the United States, each working with a different process; the difference being in the methods adopted to prevent the impairment of the preservative treatment by the washing out of the zinc salt, which is quite soluble in water. This solubility of the chloride is the only objection to its use, but the exact value of this point is not determined to the author's satisfaction. The evidence already adduced relates to the Burnettizing process proper, in which the zinc chloride alone is injected, with no attempt at any artificial method of preventing its being washed out. However, various methods have been devised to eliminate any objection on this score, and each of the plants in operation in 1885 was working on patented ideas, with this object in view.

The Thilmany Process.

The Thilmany process consisted of the injection of sulphate of zinc or copper, followed by a second injection of chloride of barium, when a chemical change was supposed to take place in the wood ducts, the chloride of barium being changed into an insoluble salt, sulphate of baryta; its chlorine forming chloride of zinc or copper. The insoluble salt was to prevent the soluble one from being washed out. Timber was treated in this way at plants in Defiance, Ohio, and Milwaukee, Wis., and some favorable results were reported. Ties had been treated

for the Chicago and Alton Railroad in 1880, and for the Erie Railroad in 1882. The Government report of Forestry (1884) states that 200 000 soft wood ties treated by this process had been put into the tracks of the Lake Shore and Michigan Southern Railroad. Some were also treated for the Wabash Railroad.

Correct records of the ties on none of these roads are obtainable. Mr. H. C. Draper, Chief Engineer of the Chicago and Alton Railroad, recollects having made an examination of the results on his road which was unfavorable to the ties. Those treated had been of various soft woods growing along the line, and the experiments were not considered successful. No definite information as to the life of these ties can be secured.

On the Erie and the Wabash railroads the results were unsatisfactory, as evidenced by letters of the late Charles Latimer, M. Am. Soc. C. E., and W. S. Lincoln, M. Am. Soc. C. E., the Chief Engineers of these roads. It is supposed that the failures were, in part, due to the expected chemical action not taking place when the substances were confined to such small spaces as the ducts of timber.

The Zinc-Gypsum Process.

The zinc-gypsum process consisted of one injection of a solution of chloride of zinc and gypsum. It was claimed that the gypsum crystallized in the ducts of the wood, thus stopping them up and preventing the zinc from being washed out. As the process was then new, no evidence was submitted in the report, except statements of chemists showing the apparent impossibility of washing the zinc out in laboratory tests. A plant was operated at St. Louis for several years, but was not a success financially; it was dismantled, and efforts to secure any facts as to the value of the work done have been unsuccessful.

The Wellhouse or Zinc-Tannin Process.

The Wellhouse or zinc-tannin process consisted of the injection of a solution of zinc chloride containing a small amount of glue, followed by another injection of a solution of tannin, the effect of the tannin, it was claimed, being to form with the glue small particles of artificial leather, insoluble in water, which would plug up the ducts and retain the zinc chloride. A plant was in operation in St. Louis under the management of the late Joseph P. Card, Assoc. Am. Soc. C. E.

TABLE No. 1.—EXAMINATION OF TIES ON THE ATCHISON, TOPEKA AND SANTA FÉ RAILROAD.

AT TOPEKA.	JULY 2D, 1891.				
Kind of wood.	No. of ties.	Date laid.	No. now in track.	Percentage.	Years in track.
Colorado pine	49	July 7th, 1881	Destroyed by wreck.		
Cottonwood	87	August 1st, 1882	43	49.4	8.9
Sweet gum	51	"	10	19.6	8.9
Red oak	48	August 18th, 1882	29	60.4	8.8

AT LA JUNTA.			JULY 6TH, 1891.			MAY 11TH, 1893.			MARCH 14TH, 1897.		
Kind of wood.	No. of ties.	Date laid.	No. now in track.	Percentage.	Years laid.	No. now in track.	Percentage.	Years laid.	No. now in track.	Percentage.	Years laid.
Black oak	49	May, 1882	49	100	9.1	47	96	11	44	90	14.8
White cottonwood	49	" "	47	96	9.1	11	22.4	11	8	16	14.8
Cottonwood	50	" "	46	92	9.1	22	44	11	17	34	14.8
Colorado pine	50	July, 1881	50	100	10.0	20	40	11.8	None.	.....	.....

The first timber was treated in 1879. In the following years paving blocks, experimental lots of ties for various railroads and miscellaneous timber were treated. The ties were laid in the vicinity of St. Louis and on the Atchison, Topeka and Santa Fé Railroad. Regarding this work O. Chanute, M. Am. Soc. C. E., says:

"In 1885 I went to St. Louis upon the occasion of the repairing of the St. Louis Bridge. This had been laid in 1879 with gum-wood blocks prepared by the Wellhouse process. These blocks, originally 5 inches thick, had worn down so thin as to give trouble, but they were sound after 6 years' exposure. Less than a dozen were found decayed in the whole length of the bridge. The Burnettized pine stringers were also sound, and the local railroads reported ties treated by the Wellhouse process to be a success, except one lot laid in mine screenings and 'bone' at East St. Louis."

Of the experimental ties put into the tracks of the Atchison, Topeka and Santa Fé Railroad in 1881 and 1882, examinations were made by Mr. Chanute in July, 1891; of those at La Junta, Colo., and Topeka, Kans., and in May, 1893, and March, 1897, at La Junta. James Dun, M. Am. Soc. C. E., kindly had examinations made in both places in December, 1898. He found some of the treated ties still in

the track, but the tin tags identifying each tie had entirely disappeared, or had become so badly scarred that no count of any value could be made. The records of the previous examinations are given in Table No. 1.

Atchison, Topeka and Santa Fé Railroad Works.

The first road to adopt the use of the treated ties, other than as an experiment, was the Atchison, Topeka and Santa Fé Railroad, of which A. A. Robinson, M. Am. Soc. C. E., was then Chief Engineer. This road, in 1885, had a plant built, under Mr. J. P. Card's direction, at Las Vegas, N. Mex., consisting of two retorts 6 ft. in diameter and 106 ft. long, which operated on mountain pine. The Wellhouse or zinc-tannin process was used except from 1889 to 1893, when the Burnettizing (proper) method was followed. The number of ties treated was as follows:

1885	111 503	1892	187 270
1886	333 298	1893	178 167
1887	189 386	1894	247 566
1888	285 104	1895	256 887
1889	169 174	1896	336 070
1890	105 753	1897	380 523
1891	128 568		
Total	2 909 269		

These ties have been used from Dodge City, Kans., to El Paso, Tex., and Silver City, N. Mex.; and a few in Eastern Kansas and Oklahoma Territory. The majority, however, have been used in New Mexico. The life of the untreated mountain pine is given as not to exceed 4 years. Complete records of the treated ties are unobtainable, but through the kindness of Mr. James Dun, Chief Engineer; Mr. H. U. Mudge, General Superintendent, and Mr. George W. Noyes, Manager of the Las Vegas works, the following facts have been secured:

"The New Mexico Division was built in 1880, with native untreated ties. We commenced renewals in 1885, with native pine treated ties, and since that time no other class of ties has been used. The untreated ties were, of course, all removed prior to 1893, so that ties taken out since that time are evidently all treated ties.

"We have assumed that after 100% of the original ties have been removed, all ties taken out were then treated ties. For the 5 years, 1893 to 1897, inclusive, we inserted on the New Mexico Division, on 380 miles, 414 189 treated ties, an average of about 217 ties per mile per year. The renewals for this period were about normal, the ties in this track being in very good condition; therefore, the average life of these ties can be put down as 11 or 12 years.

"As to peculiarities in the length of life of ties due to the character of the soil, I have to say that in New Mexico, ties last much longer in rock ballast than in soil, and decay very much faster in sandy soil than in clay. There are still (July, 1898) a great many treated ties in track branded 1885. You will also understand that a good many of the ties removed are taken from sharp curves and were removed on account of being spike killed.

"On the New Mexico Division we are using treated native pine ties. On other divisions we have been using cedar and oak; usually oak in main lines only. The life of oak ties in heavy main line service is about 6 years; of cedar ties in light branch service, about 10 years.

"Relative to the Burnettized ties laid in 1889 to 1893, we have as yet been unable to demonstrate whether the life of these ties is less than that of the Wellhouse process, as ties laid in 1889 have not yet shown signs of deterioration."

Beginning in 1897, the records of the ties on the New Mexico Division have been more carefully kept, and for future years they will show the number of removals and the causes. Mr. J. E. Hurley, Division Superintendent, has furnished a statement (Table No. 2) covering the years 1897 and 1898.

TABLE No. 2.—TREATED TIES REMOVED ON THE NEW MEXICO DIVISION OF THE ATCHISON, TOPEKA AND SANTA FÉ RAILROAD IN THE LAST 9 MONTHS OF 1897 AND IN 1898.

Year removed.	Years of Treatment.												Total removed.	Average life.
	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.		
1897...	13 114	17 540	15 527	10 327	2 459	2 552	566	560	55	104	17	10	62 831	10¼ yrs.
1898...	14 580	17 230	24 662	18 424	5 575	3 649	1 917	5 444	1 900	274	118	49	93 822	10½ "
	27 694	34 770	40 189	28 751	8 034	6 201	2 483	6 004	1 955	378	135	59	.....	.....

"I am not able to give you the exact number removed from different causes, but would say that 1% of the total will cover all ties removed on account of being broken by wrecks and causes of a like

nature, the balance being removed on account of being rotten, worn out," etc.

The average life of the ties removed does not quite equal that estimated for them by Mr. Mudge, but it does not follow that his estimate is in error; although his premises apparently are. With the renewal of 62 831 treated ties in 9 months of 1897, and of 93 822 in 1898 it is improbable that the 414 189 ties renewed in the 5 years, 1893 to 1897 inclusive, could all have been treated ties. It will be noted that the average life of the ties removed in 1898 was longer than that of those removed during 1897; and it is understood that the 1885 ties are not yet all removed. It is natural to expect that the life of the ties removed each year will continue to increase for some years to come, certainly until all the 1885 ties are removed. As the best results can hardly be expected from the treatment of the first year, it is very probable that 12 years' life will be reached by these ties.

In the Las Vegas works, ties are steamed from 2 to 6 hours, depending upon their condition when received, green timber requiring longer time. They are in a vacuum for ½ to 1 hour, and under pressure for 2½ to 3 hours. Prior to 1890 the chloride was prepared at the works, but since then it has been purchased, in a fused condition. The purity has varied from 95 to 97 per cent. "The amount of zinc chloride injected varies in different years, varying from 0.28 to 0.47 lbs. of chloride per cubic foot of timber treated, which includes sawn lumber of all kinds and piling." Seasoned timber is preferred; and after treatment ties are at once shipped to their destination. They are then supposed to be unloaded, piled up in lots of ten, in triangular piles, so arranged that only one end of any tie is on the ground; and allowed to season for about 30 days. In point of fact, they are generally put into the ground immediately, full of water; on account of the difficulty in providing for the demands of the road with the present facilities. In Mr. Noyes' opinion, to secure the best results, ties should be seasoned for 6 months before treatment and for the same time thereafter.

In 1896 this plant was enlarged by the addition of a third retort. In 1897 a large plant, consisting of four retorts, was constructed by private parties, at Somerville, Tex., where it is expected to treat large quantities of ties for the Santa Fé system; and this railroad has just completed another plant at Bellemont, Ariz., consisting of two

retorts, where ties will be treated for that part of the system. The officials of the road express themselves as satisfied with the value of the treatment, but are discussing the relative values of the zinc-tannin and the plain zinc-chloride methods. The additional cost to inject the glue and tannin amounts to several cents per tie; and they are in doubt from their own experience whether the increased cost results in an increased life, and, if so, to what extent.

Union Pacific Railroad Works.

The Union Pacific Railroad had some experience with wood preservation in 1867 and 1868 when works were erected at Omaha and operated on cottonwood ties for 1 year, when they were discontinued as it was impracticable with the plant at hand to prepare more than one-tenth of the ties required.

In 1886 new works, consisting of two retorts, were erected at Laramie, Wyo., under Mr. Chanute's direction. They were operated for 2 years by the railroad, and 242 000 ties were treated, when work was suspended for reasons of temporary economy. It was also reported to have been because the United States Government stopped the cutting of ties on its lands, and because of prejudice on the part of some one in authority. Whatever the reason, the works were shut up, were partially burned in 1889, and were then dismantled.

While operated, the Wellhouse process was used. According to the detailed record of the operation of this plant from July 26th to August 21st, 1886, the strength of the solution of chloride corresponded to 1.90 on the Beaumé scale, representing 1.46% of chloride in the solution, and the absorption of chloride was 0.65% of the weight of the tie, or 0.78 lb. per tie, the timber (mountain pine) weighing 29.51 lbs. per cubic foot.

Mr. Wm. Ashton, Division Engineer of the road, in a letter to Mr. Chanute, dated January 31st, 1898, speaking of the preserved ties, says :

" This work was done prior to my assignment to this portion of the line, consequently I have not had the opportunity to watch the service given by these ties fully as I would have liked. For the past 3 or 4 years I have been observing what remained of them and have talked frequently with our roadmasters, one of whom I understand has been on the portion of the line on which these ties were laid since they were placed in the track. From what I know and have been able to gather concerning these ties would state as follows:

"Ties treated were native pine and spruce, Oregon fir, elm, ash, maple and oak, by far the larger number being of native pine and spruce.

"The native pine and spruce ties began to fail in 1893; those removed during this year seemed to be mostly 'top-cut' ties. In 1894 most of the top-cut and middle-cut ties were taken out, while in 1895 and 1896 practically all the pine and spruce ties in the main track were removed. These ties were not cut by the base of the rail as badly as untreated ties of the same timber, and their failure could seldom be attributed to this cause. It was observed that the heart and bottom of these ties failed first, leaving a hard shell-like top. There are still a number of these ties in sidings.

"The Oregon fir ties were usually small, 7 x 8 ins., and were found to split badly in spiking. They failed a year or two sooner than the native pine and spruce ties.

"The elm, ash and maple ties have all been taken out during the past 4 years. The service of these ties would have seemed to be about the same as those of native pine and spruce.

"A few of the oak ties are still in the main track. We find they are getting very brittle and are breaking badly. They will probably all be taken out during the years 1898 and 1899."

The above report indicates an average life, for the mountain pines and spruces in the main track, of about 9 years. In January, 1896, Mr. Ashton read a paper before the Denver Society of Civil Engineers, on the "Average Life of Cross-Ties on Steam Railroads in Colorado."*

In this paper he says:

"Under ordinary circumstances my experience on the lines in Colorado has been that ties of Colorado pine, balsam and white spruce will last in track 3½ to 4 years under ordinarily heavy traffic. Under light traffic on a well-tied track, they will probably average 4 years. On our main line we usually take out about half of these ties after 3 years' service, and the balance the fourth year."

This would indicate the result of treatment on these ties to be an unqualified success, although the life attained is materially shorter than that reported for the Atchison, Topeka and Santa Fé Railroad, with practically the same material, but perhaps a drier exposure.

At the author's request, Mr. Berry, the present Chief Engineer, had an analysis made of the chloride of zinc remaining in one of the mountain pine ties taken out of the track in 1898, after 11 or 12 years' service. The analysis showed 0.146% by weight of the chloride, the amount being the same in samples from the center and from near

* *Journal* of the Association of Engineering Societies, Sept., 1897.

the outside of the tie. In the report of Mr. W. L. Robinson, chemist of the road, he says: "The ties, when first taken from the works, seldom carried over 0.25% of metallic zinc" (or 0.52% of zinc chloride). "The ties (analyzed) are in a very good state of preservation."

Works at Chicago, Ill.

This plant is the successor of the St. Louis plant, in which the Wellhouse process was originally worked by Mr. J. P. Card, and was built in 1886 by Mr. Card and Mr. Chanute, operating under the name of The Chicago Tie Preserving Company. It consisted first of two retorts, to which a third was added in 1891 and a fourth in 1894, and has treated, up to December 31st, 1898, 4 007 946 ties for the Chicago, Rock Island and Pacific Railroad, besides small lots for other parties. The usual methods of the Wellhouse process were followed until 1896, when a modification was introduced, consisting of the omission of the glue from the zinc-chloride solution and the subsequent injection of the glue separately, followed by a third injection of the tannin.

This change was based upon experiments, and the idea that the admixture of glue with the chloride solution lessened its fluidity and consequently increased the difficulty of securing the injection of the desired amount of the chloride. It might also be argued that the province of the glue being with the tannin simply to plug up the ducts to prevent the washing out of the zinc, the only proper place for it is at the ends of the ducts and medullary rays; and that it is unwise to introduce into the body of a tie perishable organic material, like glue, to increase the duty of the chloride, and where it is practically impossible to force the tannin to it, by a subsequent injection. This modification, by necessitating three injections in place of two, somewhat increases the expense of the treatment, and while it is undoubtedly an improvement, the period of its use has been too short to demonstrate it, in increased life. The best evidence of its value is in the increased absorption of chloride obtainable.

The ties treated for the Rock Island road have been entirely hemlock and tamarack. The number by years is given in Table No. 4. The number of tamaracks being relatively small, no distinction between them is made in the following, except where the tamaracks are specifically referred to.

It is extremely unfortunate that the records of service of these ties are incomplete and of doubtful value. It is stated that practically none of the ties was removed from the track until 1892. At the time they began to come out, instructions were issued by the management of the road, that all treated ties removed should be piled up and not destroyed until inspected by a representative of the Tie Preserving Company. This was done in 1892 and 1893, except for those removed from a lot of 39 604 shipped west of the Missouri River in 1886; the removals in 1892 being 2 319 or 2.1% of the ties laid 6 years before east of the Missouri River; removals in 1893, 14 282, or 3.8% of those laid 6 and 7 years before, in 1886 and 1887, or 13% of those laid in 1886. The removals for these 2 years, 16 601 ties, represent 15.3% of those laid in 1886 east of the Missouri River, so that at this time there were still in service 84.7% of the ties laid 7 years before.

In the years subsequent to 1893, the ties removed were not inspected and counted by an agent of the Chicago Tie Preserving Company, but were reported by the section foremen to the roadmasters, and by the latter to the Superintendent of Maintenance of Way, who compiled a general statement. The removals, as given for the tracks east of the Missouri River for the years 1894 to 1897, are shown in Table No. 4. From these statements of the annual removals it was computed by the Tie Preserving Company that the average life of the treated ties was 10¼ years, an increasing percentage coming out each year, up to the twelfth, when all were supposed to have been removed.

Within the past year doubt has been thrown by some of the railroad officials, upon the accuracy of these yearly returns, and it has been claimed that the ties were averaging less than 7 years. Unfortunately, the ties were not marked in any way to indicate the year treated, until quite recently, and there had been very considerable changes in the divisions of the road, in the sections and in the methods of managing the track system. The records have become inextricably mixed, so that it is impossible to determine when and where the earlier treated ties were laid. This reduced the question of the average life to a matter of recollection and opinion, and while opinion had been favorable up to 1894, it now swung the other way. Finally, in July, 1898, Mr. H. A. Parker, Second Vice-President and Chief Engineer, ordered a count by sections to be made on August 1st, to determine how many

ties of each kind (oak, cedar and treated hemlock) were then in the tracks of the road, each section foreman counting the ties on his own section.

The result of this count is shown in Table No. 3.

TABLE No. 3.—TIES IN TRACKS OF CHICAGO, ROCK ISLAND AND PACIFIC RAILROAD, AUGUST 1ST, 1898.

Kind of tie.	White oak.	Cedar.	Treated hemlock.	Pine.	Treated pine.	Totals.
In main track	4 541 235	3 308 675	2 545 240	29 249	93 940	10 518 339
" side "	484 626	877 143	345 948	4 586	10 010	1 722 313
Totals	5 025 861	4 185 818	2 891 188	33 835	103 950	12 240 652
Percentage in sidings	9.7	21	12	13.5	9.7	14.1

The totals in Table No. 3 represent averages of 2 430 ties per mile in sidings, 3 050 ties per mile in main track and 2 950 ties per mile in all tracks. Mr. Parker is satisfied that this total number of all ties is substantially correct. The treated pine ties shown in the table were treated at works in Texas.

It remains to deduce from these figures the probable life of the treated ties. Up to the same date (August 1st, 1898) there had been treated, hemlock and tamarack ties to the number of	3 860 295
Less, shipped to the Rock Island and Peoria Railroad and not in above count	72 194
Total to account for	3 788 101
" counted in track	2 891 188
Balance presumably renewed	896 913
The treated ties were at that time being shipped west of the Missouri River, a distance of from 500 to 1 000 miles, and many were in transit, there having been shipped from the treating works during the last ten days of July, 29 209 ties; and there were also, certainly, some distributed but not in track. Assuming as fair to deduct for these two items	50 000
Leaves, as the probable renewals	846 913

This absorbs all the ties treated up to 9 years previous, or to the close of the treating season of 1889, amounting to 825 796, of which 21 623 had been shipped to the Rock Island and Peoria Railroad, so that the tracks under discussion received 804 173.

Leaving, presumably, to come from the ties treated in the following year, 1890, 42 740.

This number is 17% of the ties treated in 1890 and is to be deducted from the 9 years, leaving 8.83 years as the probable average life of these treated ties, provided there was no material error in the general count made in August.

The author does not consider this count conclusive as to the life of the treated ties on this road. The time thus determined is shorter than indicated by the removals during 1892 and 1893, in the latter year there being still in the track 85% of the ties laid 7 years before; and as indicated by ties laid on four sections of the same road west of the Missouri River; as well as by those tested on the Pennsylvania Railroad and the Duluth and Iron Range Railroad, as described later. It is extremely difficult to distinguish the treated hemlock and tamarack from cedar, by surface inspection in the track, if indeed it is possible to do so in many cases without cutting the tie, and it seems quite possible that many treated ties may have been reported as cedar; but, in the author's opinion, based on personal experience with the ties, the mistaking of cedars for hemlocks and tamaracks would not be as likely to occur. The only reason given for doubting the annual reports was that they were based on the reports of the section foremen, and had been made in the regular course of work, without any especial effort to secure accuracy. Since the August count, however, orders have been issued to keep these records accurately, and this paper has been held open until the reports of the renewals for the year 1898 became accessible, in order that the probable value of the previous year's reports could be gauged by this one. Table No. 4 gives this as well as all other data that can be secured. It will be noted that the total renewals on the lines east of the Missouri River are 481 947. The total number of treated ties put into the same tracks for the years 1886, 1887 and half of 1888 is 461 765; so that, if the annual reports of ties removed are correct, all ties put in since about the middle of 1888 are still represented in service, and the average life of over 10 years, as figured by the Chicago Tie Preserving Company,

is correct. Since the above was written it has been discovered that the treated tamaracks in the tracks west of the river have been confounded with the treated pines and reported as such—to what extent is unknown. While the number so omitted from the count of the "hemlocks" cannot be very large, it may be 50 000, and the life of the treated ties would be correspondingly increased.

All these figures, based on removals without any knowledge of the year of treatment of the particular ties removed, are extremely unsatisfactory and unscientific; but they are the best obtainable and are so presented.

TABLE NO. 4.—TREATED TIE RECORD, CHICAGO, ROCK ISLAND AND PACIFIC RAILROAD.

Year.	No. treated.	Shipped west of Missouri River.	Shipped to R. I. & P. R. R.	Remainder charged to track east of Missouri River.	Removals from tracks east of Missouri River.
1886.....	148 816	39 604	8 048	101 164	.....
1887.....	265 377	.....	3 060	262 317	.....
1888.....	201 272	.....	4 703	196 569	.....
1889.....	210 331	.....	5 812	204 519	.....
1890.....	253 245	.....	27 271	225 974	.....
1891.....	339 423	981	23 300	315 142	.....
1892.....	325 736	15 123	.....	310 613	2 319
1893.....	405 267	100 000 (?)	.....	305 267	14 282
1894.....	430 362	110 048	.....	320 314	33 344
1895.....	368 630	225 669	.....	142 961	62 245
1896.....	297 252	213 613	.....	83 639	71 695
1897.....	425 459	324 876	.....	100 583	137 708
1898.....	336 776	283 612	.....	53 164	160 354
Total.....	4 007 946	1 313 526	72 194	2 622 226	481 947

In 1886 a large number of treated hemlocks and untreated white oaks was laid in the tracks on Sections 1, 2, 5 and 9, west of the Missouri River. The renewals on these were reported in the years 1891, 1892 and 1893.

Inquiries in 1898 showed that no later separate accounts had been kept, but the Roadmaster, Mr. J. D. Sullivan, in September of that year, had a careful count made to determine the number then in the track. These various figures are given in Table No. 5. It will be noted that on Sections 1 and 2, 28.9%, and on Sections 5 and 9, 58.8%, of the treated hemlocks were still in service after 12 years. Mr. Sullivan adds "the ties still in the track are in fair state of preservation, and the best will last 4 years more." The record of the oaks is also given in Table No. 5.

TABLE No. 5.

Section.	No. of ties.	Renewed in 1891.		Renewed in 1892.		Renewed in 1893.		No. in Track Sept., 1898.		Percentage removed.	
		No.	Percentage.	No.	Percentage.	No.	Percentage.	No.	Percentage.		
					Treated Hemlock.						
1....	8 000	0	0	0	0	200	2.5	1 488	18.6	81.4	Average, 71.1
2....	8 000	0	0	0	0	425	5.3	3 137	39.2	60.8	
5....	3 050	0	0	0	0	67	2.2	1 963	64.4	35.6	Average, 41.2
9....	2 800	0	0	0	0	0	0	1 477	52.7	47.2	
	21 850	0	0	0	0	692	3.2	8 065	36.9	63.1	
					Natural White Oak.						
1....	10 000	0	0	487	4.9	800	8.0	3 184	31.8	68.2	Average, 74.1
2....	10 000	418	4.2	658	6.6	1 120	11.2	1 983	19.8	80.2	
5....	15 000	150	1.0	576	3.8	805	5.4	2 732	18.2	81.8	Average, 74.5
9....	15 200	282	1.8	685	4.5	1 335	8.8	4 979	32.7	67.3	
	50 200	850	1.7	2 406	4.8	4 060	8.1	12 878	25.6	74.4	

Mr. Sullivan states that in 2 years practically all the oaks will have been removed.

On Sections 1 and 2, 71% of the hemlocks and 74% of the oaks had been removed after 12 years and on Sections 5 and 9, 41% of the hemlocks and 74% of the oaks. As to the variation in the life of the hemlock on the different sections, Mr. Sullivan says:

"The cause is the difference in dirt and ballast, Sections 1 and 2 being close to the Missouri River, and dirt, largely silt and sand, with 3 miles of rock ballast in the former. Sections 5 and 9 are 24 and 48 miles west of the river, and the ground is largely black firm prairie loam. All kinds of woods, except cedar, are short-lived in river bottom and bluffs."

If the hemlocks now in the tracks last 4 years longer, for the best, as Mr. Sullivan states, it is fair to put the average remaining life of all the ties now in at 2 years. On this basis the average life of all the treated ties would figure for

Section 1..... 10.27 years.
" 2..... 11.13 "
" 5..... 12.34 "
" 9..... 11.62 "

or for all four sections 11 years. These averages are derived thus, taking that for the four sections as an example:

Renewed in 1893, after 7 years' service	3.16	×	7	= 22.12
" 1894, 1895, 1896, 1897 and 1898 (average 9½ years)	59.94	×	9½	= 569.43
Remaining in track now, good for 2 years more	36.9	×	14	= 516.60
	100.00	×	11.08	= 1108.15

Average, 11.08 years.

The life of the treated ties on this road has undoubtedly been less than is readily obtainable by a more rational practice than was the custom prior to 1895. Until then the Tie Preserving Company treated all ties sent to it, regardless of their condition as to moisture or soundness. Since 1895 this has been changed, and the ties are re-inspected, when received at the works, by the Preserving Company's men, and if not sound are condemned and turned back to the tie contractor; and if the ties are too wet for treatment, they are piled up until sufficiently dry to take the proper amount of chloride.

In 1890 the Chicago Tie Preserving Company treated some experimental ties for the Duluth and Iron Range Railroad. These consisted of 85 white pines, 85 tamaracks, and 86 Norway pines. They were cut during the winter of 1889–90, treated in October, 1890, and placed in track very soon after, together with 10 Norway pine, 10 white pine and 10 tamarack untreated ties, which were cut at the same time and off the same land as those subjected to treatment.

"The roadbed in which these ties were laid is in glacial drift and is what you might call gravelly hard-pan, carrying some lime, and the drainage is good; the ballast is a fairly clean and reasonably coarse gravel."

Mr. J. L. Greatsinger, President and General Manager, had an examination of these ties made in February, 1898, and wrote Mr. Chanute as follows:

"In the winter of 1895 and 1896, we were obliged to tear up the track with dynamite where these ties were originally laid. In doing so, very few of them were broken, but nearly all of them went through the ordeal remarkably well and were relaid in double track in the spring of 1896, as the grade at this point was lowered about 8 ft. At this time an inspection was made of them, and it was decided to lay part of them the same side up as before, while a few of each kind were reversed; and as the same rails, 80 lbs., were used in relaying, it did

not necessitate, except in a few instances, making new spike holes, and where this was done the old holes were plugged.

"While we have but 5 or 6 ins. of snow, yet it is difficult to give as close a report on their condition at this time as it will be next spring, but I am now able to report as follows:

"*White Pine (One Notch).*—The rail has cut into the tie but very little, the greatest depth being $\frac{1}{8}$ in. By cutting into the top of one of the ties, the wood appeared apparently as good as new.

"*Tamarack (Two Notches).*—The rail has cut into them a little more than the white pine; about $\frac{1}{4}$ in. All sound, and otherwise appear as good as new.

"*Norway (Three Notches).*—The rail has cut into these about the same as tamarack, a $\frac{1}{4}$-in. cut in the top of the tie. Found the wood in fair condition, but not as good as either tamarack or white pine.

"In general terms, the process of preservation has not only prevented decay, but has made the wood much denser, thus materially reducing the cutting usually done by the base of rail, and judging from the results already attained, these ties are yet good for 15 years, and, had we used tie-plates, for a much longer time, as the destruction of the tie will be from wear and not from decay.

"Next spring I will take out some of each kind and send you some sections of them under the rail bearing and through the spike holes, which will enable you to see the effect.

"I send you by express, some pieces that were cut from the ties the first of this month, for your inspection. I consider this a good showing, as our service on ties is the most severe of any I know of in this country, as there have been times when we have averaged for every day in the month over 100 trains passing over them every 24 hours. Our heaviest standard locomotive, ready for service, weighs about 120 tons, and our average ore car, loaded, carrying 24 gross tons in a car, itself weighing about 24 000 lbs.; length over all, 24 feet."

In response to an inquiry by the author, Mr. Robert Angst, Chief Engineer, under date of June 22d, 1898, writes:

"The untreated ties you inquire about have reached the end of their career, and are now in the ash heap. They were a fair average of the untreated ties on our line, the effective life being between 7 and 8 years."

In 1891, 200 tamarack and 200 hemlock ties were treated for, and placed in, the tracks of the Pittsburg, Fort Wayne and Chicago Railway. Thomas Rodd, M. Am. Soc. C. E., Chief Engineer, says of them (1898):

"After these ties were put in the track we watched them pretty carefully and for about 3 years they cut rather more than an oak tie.

After that, however, they seemed to cut less than an oak tie, and are to-day in good shape in our main track."

In the spring of 1898 two of these ties had decayed, and were removed. An examination after removal satisfied Mr. Chanute that the two ties were from dead trees, and their failure after 7 years' service he attributes thereto. In 1896 and 1897 the same road put in track about 50 000 hemlock preserved ties; and during 1898 there have been treated for it 13 000 beech and 11 000 black and red oaks.

The Maintenance of Way Committee of the Association of Transportation Officers of the Pennsylvania Lines made a full report on the subject of ties 2 or 3 years ago, in which it was recommended that 100 000 ties, preserved with zinc chloride, should be laid each year on their lines.

There have been a number of ties treated for the Rock Island and Peoria Railroad, a subsidiary line of the Chicago, Rock Island and Pacific Railroad, operated under separate management. An effort was made to secure data from this road as to its experience with these ties, but nothing but very general statements could be had. From the Chicago, Rock Island and Pacific Railroad it was learned that the number of treated ties delivered to the road was as follows:

1886	8 048
1887	3 060
1888	4 703
1889	5 812
1890	27 271
1891	23 300
Total	72 194

In response to an inquiry, Mr. J. E. Breckenridge, Roadmaster, wrote, under date of June 27th, 1898:

"Our ballast at that time" (when the ties were put in) "was mostly gravel, and cinders in places on top of gravel. On prairie soil, gravel ballast, ties lasted about 4 years; on timber soil, gravel ballast, about 7 years; around coal shafts with slack ballast, about 3 years. I think those ties might have done better had they been piled up for one year and got thoroughly dry. The ties seemed to come to us from the vat, and were generally put in track very soon after they were received."

In reply to a later inquiry as to the number and location of any ties still in track, Mr. Breckenridge wrote: "There are none of the ties you speak of in track now."

The author could see no reason to expect any such short life for the ties as this indicated, judging from the experience of others with them; and as inquiries of the higher officials of the road produced similar views to those of Mr. Breckenridge, it was determined to test by actual examination and count, the statement as to the ties being all out; and to determine the reason, if such was the fact. Accordingly, S. M. Rowe, M. Am. Soc. C. E., who was for some time in charge of the Las Vegas treating works, was engaged to walk over the entire line of 118 miles and count all the treated ties he could find. Mr. Rowe made this examination in November and December, 1898, and in his report practically gave the number of ties on each mile separately, so that his count could be readily verified or disproved. He absolutely identified 20 272 treated ties and estimated that there were 2 000 more covered by snow or surplus ballast—practically 30% still in service—indicating how easy it is to lose the reckoning of ties in track. Mr. Rowe states:

"The ballast consists about as follows: From Rock Island yard to Milan, mostly sand, quite fine, taken from local sand pit. The main line eastward as far as Toulon is mainly fine gravel, some places very profuse, covering the ties many places so as to prevent inspection, while much of the distance the ballast is thin.

"Almost all of the coal branch, and that portion of the main line east of Toulon, is ballasted with burnt clay, a very good material for the purpose. The burnt clay ballast is in ample quantities, covering the track entirely for considerable distances and banked against the ends of the ties so as to materially retard drainage.

"In consequence of this, the track is down and ties are churning in the softened track. To what extent this has affected the lasting qualities of the cross-ties, I am not prepared to say, but the matter is here noticed with reference to that question.

"The identification of the treated hemlock ties was not difficult, as the grain of the wood, the presence of bits of the bark and the well-defined shade of the surface of the timber, were all an aid in this; but the most striking characteristic of the hemlock was what I would call its 'integrity'; that appearance of soundness of wood, and especially the absence of material wear under the rail. To fully understand this, a personal examination is necessary, as while the superiority of these treated ties is so marked, the actual condition is hard to put into

words to express it fully. This is especially noticeable between Crampton and Orion on the Cable Branch.

"In regard to the identification of the tamarack it was found very difficult, as the difference of the grain from that of the cedar was less marked, and only the greater firmness of the wood and the shade of color due to the treatment were available, and, in consequence, many were missed in checking.

"Without a more searching examination of these ties yet in track, it is difficult to form an opinion as to the time they will serve. I would judge that perhaps 25% would be removed in a relaying of the track, and that the service of the other 75% would be from 2 to 5 years if properly handled. Very few of the ties (hemlock) were found in the waste piles.

"The resistance to rail wear was remarkable, and when the hemlock was laid with oak, the wear was inappreciable. When laid here and there, interspersed with cedar, the wear was greater, but still insignificant compared to that of the cedar, and this fact aided very much in finding them."

Southern Pacific Railroad.

The profession and the railroads owe a great debt to Mr. J. Kruttschnitt, General Manager of the Southern Pacific Company, for the very careful and complete manner in which he has had kept the records of the ties treated and used on his road. His is the only company which can furnish complete data on the subject; and when the labor entailed is considered, especially after preliminary tests have indicated the success of the treatment, so that there is some confidence in it, it is the more remarkable that he has so consistently and constantly devoted so much of his own time to it, as is necessary to insure its continuance. There can be no question of the value of these records to the railroad, and the slight expense is thoroughly justified, and would be, even if much greater than it is. One of the difficulties in connection with the treatment of ties in the United States in the near future is likely to be this one of proper records. Treated ties, like the untreated ones, will show great, and, to the casual or superficial observer, entirely unaccountable, variations in life; and, unless it is possible to determine definitely by total averages the life secured from the ties, there are apt to be periods when those in authority will conclude—from impressions, not records—that treatment is a failure and a waste of money. Even under favorable conditions, ties will develop eccentricities which will demand investigation

and expert consideration, if the best results are to be obtained. This has been the case already in several instances in the United States and abroad, and as more roads adopt the process and attempt to let it run itself, failures are bound to occur, without the records which, if properly kept, would indicate the cause and permit the remedy to be applied.

All the treated ties on the Southern Pacific Railroad, except the bridge ties, which are creosoted, are preserved by the old original Burnettizing method, viz., the injection of chloride of zinc only, with no other treatment to prevent the leaching out thereof. The use of these ties was commenced on the Texas and New Orleans road, a part of the Southern Pacific, Atlantic System, in 1887, and until 1891 they were treated at the works of the Houston and Texas Central Railroad, at Houston, Texas; after that date, at the plant of the Southern Pacific road, erected near the same place.

The operations on this road are described in a very complete and thoughtful report made to Mr. Kruttschnitt by Mr. J. T. Mahl, Engineer of Maintenance of Way of the Atlantic System, under date of July 9th, 1898. The following data are from this report, supplemented by information in letters by Mr. Kruttschnitt; the quotations are from from the report:

"The timber treated is long-leaf and short-leaf yellow pine from Eastern Texas and Western Louisiana." It is all sap wood, and, untreated, has a life of only 1½ to 3 years, being the cheapest wood obtainable. The heart wood of the same timber, untreated, would have a life of from 6 to 9 years.

"It is felled at all the seasons of the year, and no attempt is made to season it, either before cutting into ties or after receiving it at the works, previous to treatment." However, "in treating the large number of ties we are called on to treat for this company and its affiliated lines, some timber necessarily must be stored at the works, and this receives natural seasoning to some extent. When ties are treated some care is taken in charging the cylinders to fill them as nearly as possible with ties of the same age, so as to secure uniform treatment; for if green ties and ties which had been seasoned for 3 to 6 months were subjected to the same treatment, the percentage of absorption of the seasoned ties would be much greater than the absorption of the green ties."

The strength of the solution of chloride formerly used was 2½° of the Beaumé scale, corresponding to 1.7% of chloride; and from 0.70 to

0.75% by weight of the pure chloride was injected. As many ties shattered and split under traffic, it was concluded that the strength and quantity of the injection was too great, and this has been gradually reduced until the strength is now represented by 2⅓°, and the quantity is from 0.50 to 0.55 per cent. In the author's opinion, this is probably a mistake. In Table No. 9 it will be noted that of 92 206 ties removed from six districts during 2 years and 4 months, 87% were rotten, and only 11% were removed because of shattering. Of course the limiting line between decay induced by shattering under the rail and that acting on the tie generally is difficult to define, and these figures may not fairly represent the relative difficulties from the two causes. This trouble with shattering has been found elsewhere with different material and with very much higher strengths and larger quantities of the chloride, without, however, developing into any very serious matter. The German practice at some works is to use a solution 3° strong, and the specifications for treatment at the J. Ruetgers Works require, in case of green or close-grained wood, into which it is impossible to inject the required amount of solution of 3° strength, that this strength shall be increased even up to 4½°, so as to secure the presence of an equivalent amount of the zinc chloride in all ties. The Chicago Works use at times a 3.8° solution and now inject 1% of chloride; and yet, out of 4 000 000 ties treated, not one broken tie has been reported. The proportion of those shattered to pieces is unknown, but is believed to be small.

The best German expert advice is to the effect that the change in strength from 2½ to 2⅓° is entirely too small to affect at all the strength of timber. If the shattering at any time exceeded or nearly approached the destruction by rot, it was more probably due to the use of excessive heat or impure chloride.

"With few exceptions the treated ties have been used exclusively in the main line between Houston and El Paso, a distance of about 836 miles." Tables Nos. 6, 7 and 8, give very complete data as to the life of ties on the Atlantic system, which includes the above.

To obtain the information regarding treated ties "it has been the practice of the company to stamp the ends of the ties, immediately after treatment, with a brass die giving the month and year of treatment. Track foremen have been required to put the stamped ends of all ties upon the same side of the track, that is to say, on the right hand going from New Orleans to El Paso. Foremen are provided with

an especially prepared blank on which they are required to report at the end of each month, the number of treated ties of the same date, removed by them; also the causes of removals of these ties, that is to say, whether rotten, shivered or broken, or from miscellaneous causes. These reports are then forwarded to the office of the Engineer of Maintenance of Way, where they are consolidated."

TABLE No. 6.—CLASSIFICATION OF TIES IN TRACK, ATLANTIC SYSTEM, SOUTHERN PACIFIC RAILROAD, JUNE 30TH, 1897.

Kind.	Total number.	Percentage of whole.
Cypress	3 051 476	49.6
Untreated heart pine	1 019 435	16.6
Creosoted ties, principally bridge ties.	42 804	0.7
Burnettized sap pine	1 704 012	27.7
California red-wood,	323 371	5.3
Oak	9 214	0.1
Totals	6 150 312	100.0

TABLE No. 7.—TIE RENEWALS, ATLANTIC SYSTEM, SOUTHERN PACIFIC RAILROAD.

Year.	Miles of track including sidings.	Number of ties renewed of all kinds.	Percentage of removals to total in use.	Average percentage per year for 5 years.
1887	1 931.56	498 581	9.8	.....
1888	1 946.86	589 969	11.5	.....
1889	2 018.66	508 150	9.5	.....
1890	2 025.22	410 153	7.5	.....
1891	2 049.07	497 617	9.2	9.5
1892	2 063.18	495 287	8.8	.....
1893	2 085.32	428 053	7.3	.....
1894	2 128.65	365 393	6.1	.....
1895	2 175.97	430 014	7.0	.....
1896	2 192.87	431 628	7.0	7.24
1897*	2 198.28	231 460	3.8	.....

* For 6 months only, from January 1st, 1897, to June 30th, 1897.

The figures for removals in 1893 include the removals of previous years, separate figures for which were lost.

"It will be observed from Table No. 8 that nearly all the 1887 ties have been removed, whilst an unusually large number of 1888 have also been taken out. Our records for these years show that a large percentage of the removals was due to the ties having been shivered and broken."

This is attributed to the fact that during the first few years the timber was overheated, the temperature in the cylinders being at

TABLE No. 8.—Treated Ties Laid and Renewed, by Years, Atlantic System, Southern Pacific Railroad.

Year treated.	Number of treated ties laid in same year.	Year removed.					Total number removed.	Number of years laid in track in July 1st, 1897.	Percentage remaining in track July 1st, 1897.
		1893.	1894.	1895.	1896.	1897*.			
1887.....	4 144	472	1 020	1 156	1 401	95	4 144	10	0
1888.....	118 098	3 199	3 602	10 665	16 883	9 419	43 768	9	63
1889.....	196 365	528	547	3 337	5 545	3 867	13 824	8	93
1890.....	212 677	69	67	940	3 536	4 424	9 036	7	96
1891.....	180 670	.....	8	185	936	1 035	2 164	6	98,8
1892.....	247 179	.....	.....	46	336	444	826	.....	.....
1893.....	179 229	.....	.....	269	177	120	566	.....	.....
1894.....	190 769	.....	.....	6	18	79	103	.....	.....
1895.....	190 802	.....	.....	.....	129	1	130	.....	.....
1896.....	165 783	.....	.....	.....	.....	1	1	.....	.....
1897	86 737	.....	.....	.....	.....	.....	.....	.....	.....
Total number removed.....		4 268	5 244	16 604	28 961	19 485	74,562	.....	.....

* These figures are for six months only, from January 1st to June 30th, 1897.

times as high as 300° Fahr.; and also to the strength of the solution. The latter has already been commented upon. The average life of the ties treated in 1887, considering the 472 reported as removed in 1893 as actually coming out that year, is 8 years, the amount of error from this assumption being small. Of the later years the average life of the ties treated cannot now be figured, as many of them are still in service. Of the 1888 ties 63% were still in track after 9 years' service; of the 1889 ties, 93% after 8 years' service; of the 1890 ties, 96% after 7 years' service.

It is not claimed that the decrease in the percentage of renewals of ties of all kinds during the past 10 years from an average per year of 9.5% for the years 1887–91, to an average of 7.24% for the years 1892–96, is due solely to the use of the preservative process; but, in the opinion of Mr. Kruttschnitt, that is an important factor in it. He says:

"Many years ago I became convinced that the greatest economies that could be effected in railroad operation would be those effected by the treatment of timber. From the year 1885 when I assumed charge of the Atlantic System, I have been consistently working to the policy of using nothing but Burnettized or creosoted ties, or redwood and

cypress. The California redwood, when protected against crushing, is practically everlasting, and our statistics show the gradual increase in the number of what we might call permanent ties, and a gradual decrease of untreated pine and oak. We hope within the next 3 or 4 years to make the latter disappear entirely. The reduction in the number of ties renewed per mile is due to three causes:

"*First.*—Treatment of timber.

"*Second.*—Reduction in the use of heart pine and increase in the use of redwood and cypress.

"*Third.*—To tie-plating."

Quoting again from Mr. Mahl's report:

"The objection to the Burnettized ties, as we have treated them, is that moisture will dissolve the chloride around the ends and outer surface of the ties, thus leaving an outer shell unpreserved, the timber in the same having resumed its natural condition, which, for the class of ties we use, is poor, indeed. The extent of this washing out of the zinc is dependent upon the annual rainfall, the quality and cross-section of the ballast used and the efficiency of the drainage."

The effects of moisture on the ties in the different sections being merely conjectural, beginning in 1896 the records were so arranged as to permit each roadmaster's district to be studied independently. The results so far obtained can be considered as indicative only, but they are interesting.

The Glidden District has a length of main line of 86 miles, beginning at Houston, Tex., and extending west to Glidden. It runs through a low flat country, and is ballasted with coarse gravel which extends 3 ins. above the ties at the center of the track and slopes so as to leave the ends of the ties free. The ballast is 8 ins. thick under the ties. The average yearly rainfall at Houston is 49 ins., which is a fair allowance for the entire division. A $61\frac{1}{2}$-lb. rail with a $4\frac{1}{4}$-in. base is used.

The San Antonio District joins the preceding at Glidden and ends at San Antonio, Tex. It has a length of main line of 121 miles. The profile is undulating, the line crossing the drainage of the country. A $61\frac{1}{2}$-lb. rail, with a $4\frac{1}{4}$-in. base, is used. The ballast is the same as for the Glidden District, and the roadbed is well drained. The average yearly rainfall at San Antonio is 29.5 ins., and 30 ins. can be assumed as the precipitation for the San Antonio District.

The Del Rio District has a length of main line of 170 miles. The profile is undulating, and there are some grades of 1 per cent. The roadbed is of standard cross-section, well drained, and is ballasted

with coarse gravel. A 50-lb. rail, with a 3⅞-in. base, is used. The rainfall for the District is given by the Government Report on Climate, for 1896, as between 20 and 30 ins.

The Sanderson District has 138 miles of main line, and runs almost entirely through mountainous country, with maximum grades and curves of 1% and 10°, respectively. The rail is half 60-lb. and half 50-lb. There is no ballast, the ties lying on the natural bed of soil and rock. The rainfall is less than for the Del Rio District, being given in the Government Report as from 10 to 20 ins.

The Valentine District has 154 miles of main line, through country of the same character as the Sanderson District. The rail is about half 70-lb. and half 50-lb. The track is ballasted for 42 miles with fine gravel, and is of standard section. The rainfall given is the same as for the Sanderson District, but is probably nearer the lower limit.

The El Paso District has 161 miles of main line through country of the same character as the two preceding sections. The rail is half 61½-lb., and half 50-lb. There is no ballast. The rainfall is light, and about 55 miles of the line is through arid country; probably 8 to 10 ins. precipitation would be an average for the District. The removal of treated ties only, on these various districts, for the 28 months ending April 30th, 1898, is given in Table No. 9.

TABLE No. 9.—Removals of Burnettized Ties and Causes thereof on Six Divisions, Atlantic System, Southern Pacific Railroad, from January, 1896, to May, 1898.

District.	No. of ties removed.	Cause of Removal.						Average life of ties removed.
		Rotten.		Shivered, broken.		Accidental and miscellaneous.		
		No. of.	Per cent.	No. of.	Per cent.	No. of.	Per cent.	
Glidden	6 048	5 542	92	506	8	0	0	6 yrs. 9 mos.
San Antonio	41 691	36 750	88	4 691	11	250	1	8 " 2 "
Del Rio	15 564	14 247	92	1 240	8	77	.....	8 " 10 "
Sanderson	2 607	1 716	66	145	5	746	29	6 " 8 "
Valentine	12 899	10 911	85	1 825	14	163	1	7 " 0 "
El Paso	13 397	10 898	81	1 596	12	903	7	7 " 6 "
	92 206	80 064	87	10 003	11	2 139	2	7 yrs. 11 mos.

It should be noted that the average life given in the table is that of the ties removed, and is of little value as indicating the probable average life of a lot of ties unless the ties have been in the track long enough to have covered the life of the most durable; and instead furnishes only a minimum life. To illustrate this, Table No. 10, covering additional data for the first two districts, is given. It will be noted that the average life of the ties removed is increasing steadily. The discrepancies in the figures for the average life in the two tables are due to the first covering 28 months, while in the second the averages are for each year.

TABLE No. 10.—REMOVALS OF BURNETTIZED TIES FROM TWO DISTRICTS, ATLANTIC SYSTEM, SOUTHERN PACIFIC RAILROAD.

Year.	TIES REMOVED FROM TRACK.		AVERAGE LIFE OF TIES REMOVED.	
	Glidden District.	San Antonio District.	Glidden District.	San Antonio District.
1894....	848	4 109	5 yrs. 8 mos.	6 yrs. 2 mos.
1895....	841	10 330	6 " 5 "	6 " 10 "
1896....	1 871	16 904	5 " 11 "	7 " 9 "
1897*...	1 750	8 186	7 " 5 "	8 " 2 "
1898....	3 637	19 986	7 " 0 "	8 " 8 "

* 6 months.

In Table No. 9 the average life on the Sanderson District is much lowered on account of the large number of removals due to accidents and miscellaneous causes. On the Valentine and El Paso Districts the average is also lowered by extensive rail renewals during the last 3 years. Mr. Mahl's opinion is "that the relative difference in life shown to exist between the Glidden, San Antonio and Del Rio districts may be reasonably taken as representing the relative life of ties for those districts." Mr. Mahl states: "With few exceptions the treated ties have been used exclusively in the main line between Houston and El Paso," being composed of the Divisions previously described. By comparing Tables Nos. 8 and 9, it will be seen that the average life of all the ties removed on all the divisions in the 18 months ending July 1st, 1898, was 7 years and 11 months; and that on July 1st, 1897, of all the ties laid 8 years previously, 93% was still in the track.

"The track work on these districts during the period in question consisted by far of only ordinary section labor engaged in the repair

and maintenance of the roadbed and track. For some years past, our repairs of roadbed and track over the entire system have shown gratifying decreases each year, until, for the present year ending June 30th, 1898, these repairs will not exceed $305 per mile of main line for the part west of Houston. This is the lowest cost for repairs of roadbed and track that has ever been obtained, and it is in part attributable to the increased percentage of treated ties in track."

The results of Burnettizing were so satisfactory on the Atlantic System that a plant was built in 1894 for the Pacific System of the Southern Pacific Company, and, as the timber supplies were widely separated, for economy the entire works were placed on wheels, and when a change in location is necessary, the plant forms a train which has successfully traversed 16° curves and 3% grades. It consists of two retorts, 6 ft. in diameter and 114 ft. long, and has a capacity of 2 500 to 3 000 ties in 24 hours. The total number of treated ties in the tracks of the Pacific System, up to the end of 1897, was 1 448 315, all but 74 012 of which were placed subsequent to 1894; consequently no information is yet available as to their life. This particular plant is described in a paper* by W. G. Curtis, M. Am. Soc. C. E., and was built under patents owned by Messrs. Curtis and Isaacs, both of the Southern Pacific Railroad.

A similar plant is now under construction for Mr. O. Chanute, to treat ties for the Chicago and Eastern Illinois Railroad.

Summary and Discussion of Recent American Experience.

From the preceding, the experience of American roads with treated ties may be concluded to be generally favorable. The Atchison, Topeka and Santa Fé Railroad officials, after 12 years' trial on a large scale, believe they are getting from 11 to 12 years' service from mountain pine, having a natural life of about 4 years; while from natural white oak they get but 6 years in heavy main line service; and from cedar 10 years under light service.

The Union Pacific Railroad reports about 9 years for mountain pine and spruce. The Chicago, Rock Island and Pacific Railroad report of the count of ties now in place, indicates a life of at least $8\frac{3}{4}$ years. The unimpeached counts of removals prior to 1894 show that in that year 84.7% of the ties laid 7 years previously was still in track. The record of the four sections just west of the Missouri River, as here fig-

* *Journal* of the Association of Engineering Societies, July, 1895.

ured, indicates a life of 11 years. The experience of the Pittsburg, Fort Wayne and Chicago Railroad with hemlock and tamarack ties, only 1% having been removed after 7 years; and of the Duluth and Iron Range Railroad, with white and Norway pine and tamarack which, after 7½ years' service and after having been taken up and relaid once, were still in nearly perfect condition; furnish conclusive evidence that the treatment is efficacious, and presumptive evidence that a life of 11 or 12 years may be expected. The discovery of about the same number of treated ties in the tracks of the Rock Island and Peoria Railroad, as were laid in 1891—at which time the last were laid—demonstrates how entirely mistaken were the officers of that road as to the life to be secured from such ties, even under the unfavorable conditions existing as to drainage and ballast.

The Southern Pacific Railroad, operating on the most perishable material, with a life of only 3 years at the best, had 93% of the ties treated and laid in 1889 still in the track after 8 years. The record for the ties treated during the 2 previous years was not as good, for known reasons; however, those laid during 1887 gave 10 years' service, and of the 1888 ties, 63% was still in use 9 years later.

The woods which have been treated and used for a considerable time in regular service are the mountain pines, firs and spruces, hemlock and the sapwood of the yellow pine. The woods used experimentally are the cottonwood, sweet gum, red and black oaks, beech, tamarack and Norway and white pine. Of other timbers which have not been tested, it can be expected that beneficial results will be obtained from treating any wood which will take the treatment well; that is, into which the proper amount of chloride can be injected. This is determined by the physical characteristics of the timber, the size of the sap ducts, the thickness of their walls and the amount of gummy substance contained in the sap. It does not follow, however, that equally good service will be secured from two materials, even if they take treatment equally well. The table on page 304 shows that in the German practice their beech and pine are treated with the same quantity of chloride, but the pine has 3 years' longer life, if both are Burnettized. Treated with tar oil, the beech is apparently the longer lived by 50 per cent.

The German practice is to treat only thoroughly seasoned wood. This is generally considered to be desirable in America also, but seems

to be unattainable. Mr. W. G. Curtis, however, in his paper describing the practice of the Southern Pacific Railroad, Pacific System, already referred to, states that freshly cut ties take the treatment much more readily than those partly seasoned; so that if the ties are freshly cut, they can get six charges through two cylinders in 24 hours; while if partly seasoned, they get but five charges.

"We find the time required varies greatly with the kind of timber and with the time during which the ties have been seasoning. California mountain pine, fir and spruce require less time than Oregon fir, and all timbers are more readily treated when freshly cut. An Oregon fir tie seasoned in the air for 2 years will take double the time for the treatment required for one freshly cut. Occasionally a close-grained, well-seasoned tie will not receive the preservative at all, the fluid penetrating into the sides only about $\frac{1}{2}$ in."

While this statement is probably correct for the particular timber treated, it is entirely contrary to the practice at other places, both here and abroad. As already quoted at the Houston works of the Southern Pacific Railroad, "if green ties and ties which have been seasoned for 3 to 6 months were subjected to the same treatment, the percentage of absorption of the seasoned ties would be much greater than the absorption of the green ties." The Chicago Tie Preserving Company finds it impossible to get satisfactory work with freshly cut ties, whether of hemlock, beech or tamarack. During 1898 this company ceased operating entirely for nearly 2 months, and piled up 70 000 ties in the yard at considerable expense for rehandling, to permit them to season sufficiently to take the preservative. These peculiarities of timber, however, are not necessarily dangerous. It is simply necessary to fit the treatment to the material; and emphasizes two things: That such a cost should be allowed for treatment as to permit of occasional exceptional expense without loss, and that persons entrusted with such work should be above sacrificing the quality of their work for a small immediate gain.

The Chicago Tie Preserving Company has very kindly given access to all its notes and records, both of routine and experimental work; and by request has submitted the following statement:

"This company has made hundreds of experiments upon thousands of ties. These were tried partly by weighing individual ties before and after treatment in the regular runs, to ascertain the absorption; and partly, since 1894, by special treatments in an experimental retort, holding three ties, wherein various methods could be tested without

interfering with the regular runs. The objects in the latter were two-fold:

"*First.*—To ascertain by what modification the largest quantity of chloride of zinc could be injected without making the timber brittle. This has been attained, the amount of antiseptic absorbed since 1896 having averaged double that injected in 1886, with what results remains to be seen, while not a tie has been reported as having broken in the track.

"*Second.*—To ascertain whether the ties were in proper condition to treat, and the idiosyncrasies of various woods.

"As regards the conditions, it has been found that ties delivered early in the spring require to be treated differently than those arriving in the late summer. Sometimes the former are quite unfit and must be placed upon the ground to season. This should preferably be done in cribbed piles (when there is space enough) to allow the air to circulate between the ties. The same has to be sometimes done in the autumn, when the ties have been rafted or floated out to the vessels.

"Refractory lots of hemlocks are piled upon the ground, and a few tested month by month to ascertain their condition, It is found that they gradually improve in receptivity, so that in 6 months they absorb two to three times as much as upon their first arrival. This agrees with European experience, where ties are seldom treated less than a year after being cut, but it is the reverse of the experience of Mr. W. G. Curtis, on the Southern Pacific System in California and Oregon," as quoted above. "The same claim was made by Mr. O. Thilmany, who stated: 'We prefer green timber; dry timber has to be steamed longer. Only live and sound timber can be preserved.'

"Perhaps these puzzling contradictions are due to differences in the character of the woods treated, or in the time of cutting.

"It is well recognized that natural woods are more lasting if cut when the sap is down. Summer-cut hemlock ties tested repeatedly by the Chicago Tie Preserving Company only absorbed about half as much as those winter-cut, and it was also found that some gum and pine ties cut in Virginia, North Carolina and Georgia in September, absorbed from two to eight times as much as ties from the same woods cut in April.

"It is most desirable, before treating a tie, to know when it was cut, and an ideal condition would be to have the ties identified as to the time of their cutting, and treated in the same order.

"After treatment all ties should be allowed to dry, as is always done in Europe. Several lots were treated twice in Chicago, having absorbed in the first treatment but about 14% of their weight. All of this gain they lost in 5 months of seasoning, and 12% more; and were then in a proper condition for a second treatment.

"As regards the idiosyncrasies of various woods, it has been ascertained that hemlock and beech are much more refractory than pine, principally early in the season; that white and burr oak should not be Burnettized, but that black oak, red oak and water oak take the treatment very well, and will outlast Colorado pine. Cedar is hardened by the process, but not enough to pay for the cost of injection. Tamarack, like spruce, is an uncertain and variable wood. Some ties cut at the same time, from the same forest, were found to vary as 2 is to 1 in average absorption. This was attributed to the varying amount of resin in various trees, and after many experiments it was learned to distinguish this difference by the eye, but, as it was impracticable to sort the trees before cutting them down, the injection of tamarack was finally abandoned altogether.

"There were also great differences in the absorption of individual ties of the same age and same species of wood. In extreme cases some will take eight times as much as their neighbors, and it becomes a serious problem how to regulate the injection. It will not do to treat all kinds of wood alike, and, when a new species comes to the works, many experiments have to be tried before it is known how it is best to deal with it.

"The operations of the works are, of course, controlled by an elaborate system of measurements and accounts, so that it is known accurately how much of the antiseptics are absorbed by each run of, say, 400 ties, but it is not known how much each individual tie has taken, save in special experiments. Changes are in contemplation to circumscribe this uncertainty, and in this, as well as in other details, we shall have to profit by the experience of the Europeans, who have been preserving ties for about 50 years, and have materially improved upon their original methods."

In examining the records of tie treatments it is necessary to recognize the fact that the life of the exceptional tie, whether long or short, is of no value, except as a curiosity, and as containing a possible lesson in detail. As an instance, a tie was exhibited in the Paris Exposition of 1889 which had lasted 46 years in the track of one of the French railways. It had been prepared by the sulphate of copper (Boucherie) process, but nevertheless this process has been generally abandoned in favor of others. So far as the value of a treatment itself is concerned, such records of individual ties may be worse than useless, leading to an expectation of length of life which cannot be attained by the average, or discouraging the investigator without reason. The valuable thing is the average durability, and by this only can any results of real value be obtained.

The author has been impressed, while reading the statements of 10 years ago, with the fact that the advocates of preservative methods claimed too much. The life of treated ties was unhesitatingly put at 15 years, a limit which the occasional tie has reached, and which indeed, under favorable circumstances, the foregoing records show to have been reached by a considerable number of ties, and to which, with future treatment, as the operators become more skilful in the selection of material and its application, perhaps the average life may approach. The record of commercial use in the United States has failed to reach any such period, and it is entirely unnecessary that it should, to make the treatment desirable and economical.

The author believes his investigation has demonstrated that the cheaper woods, hitherto unused, are made fully as durable or more durable than white and burr oak, by Burnettizing; and this fact is sufficient to make the adoption of the treatment desirable for many roads, if indeed it may not be said for American roads generally.

One point this inquiry has not solved is the relative advantages of the zinc-tannin or Wellhouse process, and the old method of Burnettizing, using nothing but the zinc chloride. This hinges upon two points: The solubility of the chloride when deposited in the wood, and the efficiency of the chemical action between the glue and the tannin, required to form the particles of leather which are supposed to plug up the ducts. As to the first, there is general evidence that part of the chloride can be washed out of the timber, although it is not easily done. Mr. J. D. Isaacs, of the Maintenance of Way Department of the Southern Pacific Company, in a paper* states:

"The author thinks this objection is greatly exaggerated. He has attempted to leach this chloride out of timber with running water, but could extract only an insignificant proportion, even when the timber was in fine shavings. All the chloride could not be taken out of chips from treated timber by boiling in repeated changes of water. If leaching takes place, it is certainly very slowly."

The above applies to wood treated with the chloride only. Unfortunately, this railroad was unable to furnish any chemical analyses of treated timber which had been in service for a number of years. That the chloride is gradually leached out of material treated by the zinc-tannin process is probably true. A number of analyses of timber after years of exposure shows considerably smaller quantities of zinc

* Thirteenth Report of the California State Mineralogist, 1896.

than it is believed they originally contained. One such instance has been given in connection with the Union Pacific ties, where only about one-fourth as much of the chloride was found as was generally injected. The evidence at hand would be absolutely conclusive if it were possible to know how much the ties which were analyzed contained originally; but this is not the case, as the amount of absorption of a retort full of ties is as near an individual record as it is now possible to go; and it is possible that the tie analyzed might have been one which was refractory and took very little when treated. If such had been the case, however, the tie would probably have been of short life; and it is safe to conclude that after a certain number of years, depending upon the rainfall and the efficiency of the track drainage, the amount of chloride remaining in a tie will be so reduced as to be of no further value, whether the treatment be with zinc alone or in combination with the glue and tannin.

If the claims for the formation of the artificial leather by the tannin treatment are correct, and it is understood that this is verified by microscopic examination, it is probable that the leaching is delayed. That the treatment does not prevent the passage of moisture into the wood is evidenced by the rapidity with which the treated timber seasons, as well as by the loss of the zinc shown by the analyses. The results in future on the Atchison, Topeka and Santa Fé Railroad may determine the relative advantages of these two systems, as there are large numbers of ties now in use there treated by each. To insure the greatest success by either, however, it is believed that the injection of large amounts of chloride must be practiced, and, generally, this can be done only by using timber at least partly seasoned; and the subsequent partial seasoning before being placed in track.

Granting that certain woods may take the antiseptic in sufficient quantities even if treated green, so that it may not be accurate to say that it is necessary to good work that at least partly seasoned wood should be treated, there are certain other conditions which can be said to be essential to good work. These are pure zinc, pure acid, the absence of any free acid in the chloride solution, the use of a heat not exceeding 250° in the retorts, and sound, live timber to operate on. To treat dead or dozy wood is to waste time and chemicals. Chloride of zinc apparently has no power to stop decay which has already begun, and it is doubtful if any treatment is better in that

respect. To these may be added faithfulness and integrity of a high order on the part of those operating the works.

The output and profits of a plant can be very largely increased by the lack of the last, and the results of such lack will not be apparent until years afterward.

To make the later identification of the ties certain, so that the life realized can be determined, it is believed that nothing will prove as satisfactory as the use of dating nails, which are nails with large heads in which is stamped the current year, and which are driven in the center of the top surface of the tie when laid. The cost of such nails is but small, and they are more accessible and certain than any substitute.

Foreign Practice.

The author regrets that he cannot furnish very much on the foreign practice of recent date. In France and Great Britain, the creosote process is used almost exclusively. The Burnettized timber was apparently not satisfactory. Creosote is comparatively cheap, and the increased life of ties so treated is considered as worth the additional cost over Burnettized ones.

The roads in the German Railroad Union, however, use very generally, either zinc chloride or a combination of the chloride and creosote, as well as creosote alone. Impregnation with the chloride alone has decreased while that with the mixture of chloride and creosote has largely increased. Beginning in 1895 all the pine ties used on the Prussian State railroads were treated by the zinc creosote process. This consists of the injection of the same amount of zinc chloride, with which is mixed creosote, in the amount of 1¼ lbs. to the cubic foot of timber; the mixing being done by a peculiar process. It is claimed that the results of this treatment are much superior to those with zinc chloride alone. In 1885, the Ruetgers Works furnished one road with 171 000 pine ties treated with zinc creosote, on a 9-year guarantee. In 1894, at the end of the 9 years, only twenty-nine had become unfit for use and none of these was rotten. Mr. Chanute is about to go to Germany to investigate this process, and it is hoped that he may be able to contribute the necessary data to the discussion of this paper, so that the value of the treatment may be determined. The additional cost over the regular Burnettizing process varies with the price of creosote, but is about 4 cents per tie. The zinc-tannin process has never been used outside of the United States.

The Ruetgers Works treat ties by Burnettizing on the following specifications: The solution of zinc chloride is to be 3° Beaumé strength at a temperature of 14° Réaumur. Ties and timber are to be treated until the absorption of seasoned timber is for

Pine wood.....19 lbs. per cubic foot.
Oak " .....6½ " "
Beech " .....19 " "

" If the amount of liquid required cannot be injected in the manner prescribed because the wood is too green or is exceptionally dense, the liquid is to be strengthened in such a manner that the proper amount of water-free chloride of zinc is taken up as prescribed, namely, that to be contained in a 3° Beaumé liquid.

" From this it follows that when, for instance, only 200 kilograms can be introduced into 1 cu. m. of pine wood, the chloride of zinc bath must be made 4½° Beaumé."

The German report on railroads previously referred to gives certain tables from which the following are obtained:

TABLE No. 11.—Costs and Results of Wood Preserving for the Union of German Railroads for 1896.

Kind of tie.	Cost of crude tie.	Treated with Chloride of Zinc.					Treated with Tar Oil—Creosoted.				
		Absorption in pounds.	Cost of treatment.	Total cost.	Average duration, in years.	Cost per year.	Absorption, in pounds.	Cost of treatment.	Total cost.	Average duration, in years.	Cost per year.
			Cts.			Cts.		Cts.			Cts.
Oak....	$1.49	24.2	13	$1.62	15	10.8	15.4 24.3	21 29	$1.70 1.78	24 28	7.1 6.3
Beech..	1.01	34	15	1.16	9	13.0	66 79.2	50 59	1.51 1.60	30 34	5.0 4.7
Pine....	0.84	34	16	1.00	12	8.3	50.6 79.2	43 57	1.27 1.41	20 23	6.3 6.1

This is based on a tie 6¼ ins. × 10 ins. × 8 ft. 10 ins.

From Table No. 12 it will be seen that in 1896 about 60% of all the wood ties in the tracks was impregnated in some way; and that all of the increase in number of ties in track over 1894 was in the treated ties. Unfortunately, it is impossible to determine the number treated by each process in use by these roads, and the figures are of value only as indicating the general use of treated timber in preference to the crude.

As a matter of interest, a line is added showing the amount of track laid with metal ties or sleepers.

TABLE No. 12.—Statistical Report of the Railroads of the Union of German Railroad Administrations for the Fiscal Years 1896, 1895, 1894.

Abstract of Wood Ties, Laid in Track.										Length of track laid in metal permanent way.
Designation of railroads.	Year.	Number of wood ties.					Of the ties there are:			
		Oak.	Beech.	Larch.	Pine.	Total.	Impregnated.	Crude.		Kilometers.
German, State and private roads	1896	28 279 084	3 248 882	92 585	36 947 827	68 568 378	59 834 087	8 734 291		22 805
	1895	28 635 001	3 283 867	91 924	34 775 635	66 786 427	57 626 304	9 160 123		22 102
	1894	29 353 375	3 132 261	102 936	32 241 230	64 829 802	54 041 505	10 788 297		20 868
Luxemburg, Netherlands and other Union roads.	1896	8 769 969	49 551	.....	541 285	12 099 368	1 718 815	6 730 887		495
	1895	8 281 293	48 392	.....	538 330	11 566 538	1 597 308	6 360 733		497
	1894	7 916 896	39 083	.....	552 105	11 200 509	1 552 809	6 046 430		495
Austria, Hungary and Bosnia roads	1896	31 533 486	5 406 009	4 066 135	6 144 072	47 149 702	18 197 013	28 952 689		404
	1895	30 192 026	5 437 128	3 913 322	6 056 466	45 598 942	17 755 877	27 843 065		368
	1894	29 286 099	5 797 985	3 581 179	5 778 177	44 443 440	16 882 687	27 560 753		366
Totals of all roads	1896	68 582 539	8 704 442	4 158 720	43 633 184	127 817 448	79 749 915	44 417 867		23 704
	1895	67 108 320	8 769 387	4 005 246	41 370 431	123 951 907	76 979 489	43 363 921		22 967
	1894	66 556 370	8 969 329	3 684 115	38 571 512	120 473 751	72 477 001	44 395 480		21 858

Cost of Treatment.

It is not proposed to enter into any discussion of the economy of, or the savings to be effected by, the use of treated ties. This is something which will vary with almost every road, being governed by the cost of white oak ties, cost of the inferior tie to be treated and location. It has been attempted to determine what can be expected from the treatment and with the cost thereof given below, it can readily be determined which is the cheaper—a white oak or a treated tie, and, in the author's judgment, that is what the question resolves itself into.

Apparently the evidence is conclusive that a treated tie is superior to a white oak; but, if only equal to it, on the basis of cost in most locations the treated tie will prove the more desirable.

The cost of Burnettizing sawed pine ties 6 ins. x 8 ins. x 8 ft. on the Southern Pacific Railroad in 1893, was about 10 cents each; while in 1897

it was a little over 6 cents. This includes nothing for interest on the investment, or depreciation; however it is for a very small tie, containing only $2\frac{2}{3}$ cu. ft.; and for an amount of zinc chloride only about one-half that required by the German practice. On the basis of the cost in 1897 (which amounts to $2\frac{1}{4}$ cents per cubic foot), the use of the standard German quantity to be injected and a hewn tie of $3\frac{1}{2}$ cu. ft., this cost would be about 12 cents per tie, or $4\frac{1}{2}$ cents per cubic foot, including nothing for interest or depreciation.

On the Atchison, Topeka and Santa Fé Railroad the cost of the zinc-tannin treatment, when the works were first built, was about 15 cents; in 1892 it was about 14 cents and 13 cents for Burnettizing (zinc chloride only). In 1897 the cost (zinc-tannin) was reported as 11.6 cents; no interest or depreciation being included. It is understood that the charge made by the Chicago Tie Preserving Company is from 16 to 20 cents for the zinc-tannin treatment, covering, of course, interest and depreciation as well as profit.

The contract prices in Germany for Burnettizing are: For pine and beech, 5 cents per cubic foot, and for oak, 4 cents; for treating with zinc-creosote, 6 cents for beech and pine, and 5 cents for oak; for creosoting, 15 cents for beech and pine, and 9 cents for oak. In creosoting, the amount of creosote per cubic foot is 12 lbs. for pine, 15 lbs. for beech, and $4\frac{1}{2}$ lbs. for oak. It is understood that the oak referred to corresponds to American white oak and not to the American red and black oaks, which will absorb as much as either pine or beech.

DISCUSSION.

Mr. Lowinson.

OSCAR LOWINSON, Jun. Am. Soc. C. E.—There is no question of greater importance to the engineer using wood, under conditions subject to decay, than that of the preservation of timber. A technical knowledge of the composition of the timber, of the chemical and mechanical conditions to be met, of the effects of moisture and frost, of wear and tear, of the juxtaposition of other materials, such as iron, steel or zinc against wood, of the resistance of the material to transverse crushing, rust or rot, and the relative cost of the operation, etc., is requisite for a satisfactory answer as to whether any method, or which method, is advisable for the preservation of timber.

Owing to the great expense and trouble of making continual physical and chemical analyses, the almost impossibility of examination after application, the long period of time required to determine the success of a method, and the necessity of having perfect confidence in the integrity of those who supply the materials and apply them, the use of some method of preservation of timber is, and for years will be, only on works where methods of investigation are carried out with care, or where the user places perfect confidence in the integrity and knowledge of the parties applying the process. Failure is due to ignorance and corrupt practice as much as to fundamental error of theory.

As the author states, there has been practically no English and little German literature on the subject of value, since the report of the Committee of this Society in 1885. Such knowledge as has been obtained is in the note books of the chemists and engineers who have investigated the question. The various methods of application of preservative processes have had an almost uniform experience. "The history of engineering is strewn with wrecks of numerous methods which promised much," but, under conditions of experience, performed little. Very nearly every large railroad in the United States has at one time or another experimented in this line, and many have ultimately given up, either because of the poor results of the experiment, or for reasons beyond the control of their engineers or chemists. There has been practically no advance in this department of applied science.

"The substances which thus far have given the best results are the application of chloride of zinc, the bichloride of mercury and the products resulting from the destructive distillation of coal tar" (used in creosoting).

The literature of Preservation ably discusses these processes as applied previous to the time of the above-mentioned report. A careful reading of the author's paper will show practically all the defects

Mr. Lowinson.

and objections to the first and second processes. It will only be necessary here to add the practical difficulties which have hitherto prevented the more general application of these processes.

PRACTICAL CONSIDERATIONS AFFECTING THE ADOPTION OF PRESERVATIVE PROCESSES.

1. The Consumer.—In the everyday life of railroad maintenance the "powers that be" are appointed in most cases because of their ability to give their road a good showing on the stock market. The necessity of showing at all times a maximum excess of receipts over expenditures generally influences these representatives of the stockholders to object to the added expense of a plant, or the added cost of preserving the timber, which must thereby be entailed for the period of years until the entire track has been placed in good condition; even on the assumption that the process will be a success. It is assuming that an official would not be true to the trust held if he should increase the expense of maintenance for a single year and thereby depreciate the earning power of the invested capital, even though he might be certain of ultimate saving in annual outlay; because of the very condition, *viz.*, the property is a marketable one, and the only practical method of conducting the work is to make only such repairs as are absolutely necessary to prevent its ruin. The results of this process are seen in many large railroads. The only time of actual outlay is at the time of reorganization, or when the road passes into the hands of a receiver to whom the ultimate preservation of the property is of more importance than the question of temporary value of stock. In other words, "it is the duty of the official to run the road on a poverty basis even though at much greater ultimate expense."

2. The Process.—Besides those described, the creosote processes are the only others with which satisfactory results have been obtained. Referring to the report of the Committee of this Society, the statement, that creosoting is the most perfect method of preserving timber, still holds true. Since the publication of that report, and as the result of the investigations by the German Governments on their railroads, the attention of scientists has been devoted to the production of creosote and other products in such combinations as to be applicable without the expense of a plant for impregnation under pressure. The present commercial standing of the creosote process itself is also unsatisfactory because of its unsuccessful application in many cases, due either to insufficient impregnation or to the use of an inferior material. It may not be improper in this discussion to state the kind of creosote to be used and its composition.

In the first place, the creosote to be used is what is commercially known as coal-tar creosote. It is one of the many products derived

from the destructive distillation of coal-tar. From this are derived products covering almost the entire range of human application. Among these may be mentioned all the aniline colors, the various perfumes, essences and flavoring extracts, high-power explosives, medicines, fertilizers, saccharines, photograph developers, benzines, ammonias, antiseptics, lamp black, lubricating oils, varnish, creosote, shellac, cresylic acid and other wood-preserving chemicals, etc. Besides this material, there is a wood creosote, derived from the destructive distillation of pine, of which more will be said later. Mr. Lowinson.

The creosote must be a heavy dead oil, of the best quality, free from tar and other impurities. The ease of adulteration of this product by a mixture with naphtha, and the difficulty of detecting such adulteration without continued analyses of the material, are the probable causes of failure in most attempts where it was assumed that the genuine product was used. So extensively is the adulteration carried on that few engineers have confidence in the process because of their inability to secure this product. It is the cost of this creosote that prevents its practical application. It is necessary to know the constituents of the coal-tar product, and, at the present time, commercial reasons require that it be brought from Europe. Its composition depends upon the conditions of its manufacture. It must be dense, and have a specific gravity varying from 1.05 to 1.20. It must distil at a temperature of not less than 425°, and must be rich in its principal ingredients, naphthaline (C_{10} H_8) and anthracene (C_{14} H_{10}).

The method of impregnation, when done by outside contractors, is such as frequently prevents the inspector from knowing whether the proper material is really being injected. It is not the speaker's intention to question the integrity of any plant, but the experience of many engineers has been that deception has been practiced here to such an extent as either to drive out of competition many reputable concerns, or to so discourage the user as to cause him to despair of success. Not only is this true, but the chemical analysis of the material under inspection is a difficult process. These objections are applicable to all processes of impregnation. Properly executed, however, the results are gratifying to the engineer.

The New York Division of the Erie Railroad, 10 years ago, had ties Burnettized, and whereas, untreated, their average life was 8 years, most of these treated ties had to be replaced within 6 years. The zinc-tannin process, with the addition of glue, appeals to the thoughtful engineer as meeting most of the conditions required for a preservative.

3. The Material.—The speaker would ask the author what the depth of penetration is and what method, if any, has been adopted for the protection of the tie when cut or bruised so as to admit water and frost; also the effect of checking and the effect on seasoning of timber.

The speaker does not agree with the author that the transverse

Mr. Lowinson. crushing is a negligible quality. A series of tests made by the speaker* on the transverse crushing strength of timber gave the following ultimate values: For seasoned white pine, 550; yellow pine, 774; and oak, 1 200 lbs. per square inch.

In an interesting report on the "Strength of Bridge and Trestle Timbers" by a committee of the Association of Railway Superintendents of Bridges and Buildings, of which Walter G. Berg, M. Am. Soc. C. E., was chairman, October, 1895, in regard to transverse strength, the Committee reported and recommended as the average safe compressive strength across the grain:

Southern yellow pine.....	350	lbs.	per square inch.
Chestnut and Norway pine.	250	"	"
Spruce, cypress and cedar.....	200	"	"
Oak	500	"	"

The stresses to which a tie is subject, and which in turn contribute to its destruction, either through mechanical force or decay, are the transverse crushing resistance, torsion due to track moving and deflection of rails, the shock due to hammering by the live load as transmitted through the rail, and the elements. The results of the speaker's investigations have led him to recommend the adoption of a tie-plate between the rail and the tie whenever a preservative process is to be applied in any tie other than oak, for the very reason that, although the treatment for preservation will aid in lengthening the life of a tie, the decay is only one of the causes of destruction; and protection must be sought in every possible way. When it is seen that the safe transverse crushing strength, for instance, is only 250 lbs. per square inch, even allowing for alleviation due to stiffness of the rail, the speaker would urge as an additional improvement that the tie-plate be used.

In regard to cutting treated timber, although not so often met with in railroad ties as on street railroad or dock work, the speaker fears that it is not practicable to treat the timber in the way stated unless there be some arrangement for treating the exposed surfaces.

In the case of creosoted timber, the speaker has seen both the hot and cold dead oil of creosote applied with a brush. A street railroad in New York City is using a 6 × 6-in. "creosoted" yellow pine stringer under its heavy rails, supported on the yokes about 5 ft. apart on centers, and in a large number of cases it is found necessary to notch the stringers at the yokes. The speaker is not aware that the notched portions are undergoing any treatment, but whether or not because of this the creosoting to which they have been subjected will increase the life of the timber, time alone can tell.

Liquid Preservatives.—The necessity which has arisen in European countries for treating timber has brought about a considerable amount

* *The Engineering Record*, December 12th, 1896.

of experimenting in order to find a substitute for the expensive method of creosoting. There are two reasons for the great cost of treating by creosote. These are: Mr. Lowinson.

First.—The high melting point of the naphthaline (175° Fahr.) and the anthracene (210° Fahr.), which are the principal preservative chemicals of creosote.

Second.—The necessity of a pressure process to complete the impregnation.

There are now on the market in Europe at least two materials by the use of which it is claimed that these objections are done away with. Whether the statements of the manufacturers are true or not, the speaker is not yet prepared to state. He certainly would recommend the most exhaustive examination before adopting them. In one case it is claimed that by the addition of zinc chloride to the creosote (a combination of Burnettizing and creosoting), before the completion of the process of distillation, the chloride combines with the naphthaline (C_{10} H_8), to form yellow heavy oils, dichloride of naphthaline (C_{10} H_6 Cl_2) and chloride naphthaline (C_{10} H_7 Cl); and the anthracene (C_{14} H_{10}) is converted into dichloride-anthracene (C_{14} H_8 Cl_2) and chloride of anthracene (C_{14} H_9 Cl), which at temperatures of 100° to 200° Fahr. possess great viscosity and consequent penetrating power. The speaker has seen some remarkable experiments as to the penetrating power of this material.

Wood Creosote.—Wood creosote is a material obtained from the destructive distillation of pine. Its vital principle is paraffine as distinguished from the naphthaline and anthracene of the coal-tar creosote. A large number of so-called preservatives consist of this material, either by itself or in combination with other materials. It is not looked upon favorably as a preservative, because of its unstable composition and its solubility. The much-advertised creosote and other paints and shingle stains have this material for a basis. It is the speaker's opinion, however, that the addition of a paraffine to a paint adds nothing to its preserving power.

H. S. Haines, M. Am. Soc. C. E.—By far the largest part of the cost of operation of a railroad is devoted to wages and salaries, but if the part devoted to supplies be examined it will be found that the principal expense is absorbed in two items, fuel and timber. When the amount of ingenuity and time which has been devoted to devising means and methods for diminishing the cost of fuel per mile run is considered, and how little ingenuity has been devoted to endeavoring to extend the life of timber, it is evident that the two items are not held in proper proportion. There is hardly any subject which can come before this Society which has more economic value than the preservation of timber; and therefore the speaker has examined this paper with interest to see what could be learned with reference to the general Mr. Haines.

Mr. Haines. question of the preservation of timber, but confesses to a good deal of disappointment in finding that substantially no advance in knowledge on this subject has been made since the Committee of this Society made a report on the subject in 1885. The conclusion of that Committee was substantially that "creosoting was the most perfect process to use, but in view of the expense it may be preferable to use a cheaper process. With our present knowledge we believe the zinc-chloride process is the advisable one to use for ties in this country."

By reading this paper through it will be found that in the year 1899 we are no farther ahead, and know no more than in 1885. In fact, it is a still further disappointment to see that this paper, which has been prepared apparently with a great deal of care, the author having endeavored to gather all the information he could find on the subject, presents so little. It is all impressions, traditions and legends, with scarcely any substantial facts, except in reference to what Mr. Kruttschnitt has done. The speaker knows that Mr. Kruttschnitt is very reliable in all his statements, but unfortunately his statements only cover the period from 1894 to the present time.

In a mile of track there are about 2 600 cross-ties, costing, in the track, nearly 50 cents apiece, and their average life is about five years, which represents about $230 per mile per annum. If the life of these ties could be extended, doubled, for instance, the value of any process which would accomplish this can readily be seen.

Reference is made to what has been done in Europe, where certainly a great deal more attention has been paid to the preservation of timber than in America. The speaker's experience has been only with creosote, but extends over many years. Probably no one in this Society has had more extended experience in the use of creosote for timber on railroads than the speaker, and his conclusions are the same as those of the Committee, that it is to-day the most perfect process which can be used. The best evidence of the truth of this statement is that abroad, where the zinc-chloride and also the creosote treatment have been used for many years, they have come back partially to creosote; that is, they are using zinc chloride and creosote in combination, apparently with the view of getting a cheap substitute for the latter.

As to the use of creosote itself, of course every one has had disappointments. The speaker has had some very bitter ones. Mr. Lowinson is right in saying that if the creosote contains certain constituents, particularly naphthaline, and if it is used in certain ways, the result will be just as certain as anything known in our present experience of treating timber. There is not any doubt of it. But the so-called wood creosote is a fraud, nothing else, and any substance that is soluble in water is useless for the preservation of timber, just as anything that is proposed to be superficial in its application is of but little value, for the reason that wherever a notch is cut

in a piece of timber a surface is exposed to decay, and generally in some vital part of the structure. Mr. Haines.

This paper relates to zinc chloride, about which the speaker knows nothing; but if the subject of the preservation of timber could be discussed thoroughly and properly and with special reference to creosote as a standard, then conclusions could be reached which would be of great value, not only to railroad companies, but in every other department of industry where timber is being used; and for that reason the speaker wishes that the Society would take up this subject again with one of its committees and bring the state of the art up from 1885 to the present time, as it should be brought, in an authoritative way.

It would be useless to discuss creosote, as the results obtained with that substance are well known from experience in England and in America. The preservation of timber which is properly creosoted is almost indefinite if the proper timber, the proper substance and the proper treatment are used. But this is a question of a cheaper substitute, and the evidence here seems to be that all the cheap substances have been failures, except, perhaps, in Mr. Kruttschnitt's experience since 1894, and, of course, 5 years is too short a time in which to judge of the results. The most optimistic statement in the paper is that the life of ties is 12 years. If considerable is added to the cost of the material by the zinc-chloride treatment, and if then there is some doubt as to whether the life of the tie will be increased to 9 or 12 years, when the untreated timber would have lasted from 4 to 6, a discussion of the subject has not much practical value.

The railroads have not adopted creosoted ties to any great extent, because the users of the timber listen to everybody who comes along. Such persons have all sorts of quack treatments that are ostensibly a good deal cheaper than the real, substantial creosote treatment, which is an expensive one; and the man who is responsible for the annual results does not care to make investments, the benefits of which are to be extended over an indefinite series of years.

The speaker's treatment of timber was not so much with a view to preservation from decay as to preservation from the teredo; and in preserving wood against the teredo, of course a great part of it was exposed to the air and to moisture, in a very hot country where there is much rain. In that way the speaker learned a great deal about the value of the creosote process. In order that the creosoting may be successful the timber and the creosote must be of the right kind and must be subjected to the right kind of treatment.

The creosotes are all hydrocarbons. The lighter parts of so-called creosote are of no value, simply because they are lighter than water, and anything that is lighter than water is soluble therein; but a certain proportion of these lighter parts must be retained, in order to keep the creosote fluid, so that it can be used under pressure. To be

Mr. Haines. of any value creosote cannot be used in any other way than under pressure, and certain conditions must be complied with. The wood must be taken while it is green, and the sap exhausted while the ducts are all open. The creosote must be put in under a suitable pressure until the timber weighs a sufficient amount per foot. Mr. Lowinson has said very properly that a great deal of the value of this process depends on the integrity of the persons who conduct it. There must be some means of inspecting the timber when it is used and of knowing that it is what it is represented to be. With creosote it is entirely practicable to know that what has been paid for has been obtained.

The speaker wishes to call attention to the little progress that has been made in wood preservation, to judge from this paper, since 1885, and, further, to the fact that the subject is a broader one than the mere treatment of cross-tie timber by the chloride of zinc process; and it is to be hoped that this Society will take up the whole subject again and bring up the state of the art from 1885 to the present time. If that can be done the author will have accomplished a great deal by bringing the matter to the attention of the Society.

Mr. Boggs. J. I. Boggs, Assoc. M. Am. Soc. C. E. (by letter).—This paper is both interesting and instructive. In the year 1877 a number of creosoted pole pine ties were put in along the line of the Houston and Texas Central Railroad. During the years 1897 and 1898 the writer had charge of the tracks on the Northern Division of this line, and in the course of his duties had to relay about ten miles of steel, a number of these ties being in the portion so relaid. They were examined closely, and found to be in an excellent state of preservation after twenty years of service, hardly 5% of the total number being rejected as worn out and useless. The most serious objection to them was that the rail cut into the soft wood. This, however, can be entirely avoided by the use of a good, substantial tie-plate, and the writer feels no hesitancy in saying that fully 80% of the original number are still in service.

Various kinds of ties were in use along this line during the years intervening between 1890 and 1899, such as white oak, post oak, cedar, Bois D'Arc, creosoted pole pine and Burnettized sawed pine ties. These latter ties were small, being only 6 ins. x 8 ins. x 8 ft., and the great difficulty, as stated by Mr. Mahl in his report, was that they shattered badly under the heavy traffic to which the road was subjected.

No material record of the life of ties was kept before the latter part of 1897, and in the case of the Burnettized ties the personal observation of the writer was such as to lead him to believe that fully half the ties reported as rotten by the section foremen were shattered instead. He has examined the wood in the ties that had splintered, and the original timber was found to be in an excellent state of preser-

vation in a number of cases, although it was broken and worthless. The writer does not believe that the solution of the problem will be found in the weakening of the zinc chloride, but in the adoption of a better class of material than that heretofore used. The same objection applies to these ties as was stated in the case of the pole pine, *viz.*, that the rail cuts into the soft wood very badly, sometimes as much as 2 to 2½ ins. Six years is about the best life that could be obtained on this road, those placed in 1891 being practically all gone in 1898; but, as before stated, the reports of the section foremen on this subject are entirely unreliable, and can in no measure be depended upon as to the causes for removal. Mr. Boggs.

While the first cost of the creosoted pole pine tie is much greater than the Burnettized tie, a few years' service will readily demonstrate that it is by far the more economical.

B. M. WAGNER, Assoc. M. Am. Soc. C. E. (by letter).—During 1890 the writer visited the impregnating plant of the Swiss Nord Ost Bahn and jotted down the following notes which may be of interest. Mr. Wagner.

Zinc chloride is used. The plant consists of two cylinders, each 1.9 m. in diameter and 14 m. long; mixing tanks, each holding about 6 000 l., a 15-H.-P. steam plant and various buildings. This plant is said to have cost 120 000 francs. The cross-ties are run in on rail wagons, shaped to conform to the cylinders, each holding about forty cross-ties.

One hundred liters of zinc chloride, containing about 25% of metallic zinc are put in each of the mixing tanks and the tanks then filled up flush with water. The cost of impregnating one cross-tie is stated to be from 0.45 to 0.48 franc.

The plant is never idle, as the company is overrun with orders from outsiders. The charge is 10 francs per cubic meter of wood impregnated, while the cost, including interest on capital, sinking fund, etc., is only 4.80 to 5.20 francs per cubic meter.

The quantity of zinc chloride used per cross-tie is as follows:

Oak, 8 kls.; larch, 15 kls.; beech, 20 kls.; pine, 25 kls.

The life of ties is as follows:

	Green.	Impregnated.
Oak	15 years.	20–25 years.
Larch	9–10 "	15–17 "
Fir	7– 8 "	12–14 "
Pine	4– 5 "	9–10 "
Beech	2– 3 "	10 "

GEORGE W. NOYES, Esq. (by letter).—There are several items which the author has dwelt upon, which are of vital importance to the process. The writer, having had ten years' experience in the operation of the Atchison, Topeka and Santa Fé Railroad Company's timber-treating plant, may be able to explain more fully why results in some cases have not been what might have been expected. Mr. Noyes.

Mr. Noyes. While it is the intention of this company to use nothing but fall and winter-cut ties, it is a fact that many thousand summer-cut ties, in which the fungi had already attacked and partly destroyed the fibers, have been treated, as well as those which were practically worthless at the time of treatment. It is the habit of the native tie choppers to go into the timber in the fall and winter, and fell a sufficient number of trees to fill their sub-contracts, making the ties later on. Many of these trees are allowed to lie from one to two years with the bark on. Then they are made into ties, brought in and received as first-class and treated, when they were really worthless, as the fungoid life had already destroyed the fibers of the wood. To these two classes of ties can be attributed a large percentage of the tie failures, in the past, and those which will occur for some time to come, as it was only last season that the writer succeeded in stopping this practice.

The proper seasoning of timber, both before and after treatment, is of the utmost importance. To this can be attributed, in a great measure, the success of the 1885 ties. On account of the solubility of the zinc salt, it is necessary that all the water injected with the chloride be evaporated before the tie is inserted in the track, otherwise the moisture in the soil at once begins its work of leaching out the zinc salt, and the artificial leathery pellicles formed by the glue and tannin are of no benefit, as they have not had time to dry and harden sufficiently to offer any resistance to outside moisture.

The quality of the zinc chloride has much to do with the success of the operation. The company's first purchases of fused chloride, from 1890 to 1895, were supposed to contain from 3 to 5% of impurities, mostly moisture, but these were, in fact, much greater. In 1894 some chloride was found to contain as high as 2.5% of iron, and its effect is already being realized, as a great many ties treated in this year are entirely gone now. From 1885 to 1890 there were no less than eight different persons in charge of the plant. They were not familiar with the process, and by the time they were the works had closed, and they had sought other employment. This, the writer thinks, was detrimental to the process. It must also be remembered that the first treatment was with a 0.015% solution, injecting only about 0.25 lb. zinc chloride per cubic foot, while the more modern practice is to use nearly a 0.03% solution, injecting about 0.50 lb. of chloride per cubic foot, which should make the ties remain antiseptic for a greater length of time. The following is the record of some 1885 ties treated at these works, and laid in the main line just north of the Kaw River Bridge in North Topeka, Kan.: Of 305 ties put in track, 152 were on a tangent and 153 on a 4° curve. In October, 1895, all of those on the curve were taken out, not so

much on account of rot as wearing under the rail and respiking, which had made their general condition such that the spikes would not hold. Of those on the tangent, all were in on this date, but 22 were to come out, leaving 130 in the track. On October 31st, 1896, there were still 81 in on the tangent, apparently good for several years. The average life of oak ties at this point is 7 years. Mr. Noyes.

As to the Southern Pacific ties: In the fall of 1896 the writer spent some time in examining ties in their track, and, while the zinc chloride and steaming may be the direct cause of their failure, it is, in his opinion, due to the use of superheated steam (as he understands that they used a superheater during the first few years the works were operated), and to a particular species of timber used, as there are several species of timber which will check along the annual rings or radially if exposed to the sun or dried too rapidly by artificial heat. At the company's works, the only kind of timber treated is red spruce, which corresponds to the Oregon fir, and which treats better when green than dry. This phenomenon is no doubt due to the resinous nature of the wood, the resin, on becoming dry, forming an impenetrable barrier which the zinc solution cannot pass.

In the summer of 1896 the company treated (with zinc chloride only), for the Burlington and Missouri River Railway, in Nebraska, two sections of ties from the Big Horn Mountains in Wyoming. The original sections were 16 ft. long, half being retained there and sent to the laboratory at Aurora, Ill. The results of the tests on the treated and untreated timber are shown in Table No. 13.

TABLE No. 13.

Sample No.	Transverse strength.	Deflection.	Crushed under 30 000 lbs.	Spike hold.	Ounces of Zinc Chloride per Cubic Foot.	
					Center.	Edge.
	Pounds.	Inches.	Inches.	Pounds.		
2. Treated	2 766	0.45	0.97	2 017	0.00	12.00
Untreated	2 597	0.48	0.73	1 830	.....	.....
3. Treated	3 125	0.45	0.45	2 600	0.00	27.50
Untreated	3 066	0.54	0.54	2 400	.....	.....
5. New Mexico Burnettized Pine tie	2 975	0.45	0.61	2 775	0.24	6.80
6. New Mexico Wheelhouse Pine tie	2 975	0.38	0.73	2 470	0.62	9.43

Tests of the transverse strength were made on samples 2 x 2 ins. in section, on supports 12 ins. apart. The crushing test was made with samples 6 x 6 ins., by noting the depth to which the flange of a 66-lb. rail penetrated the sample under a load of 30 000 lbs. The figures under "spike hold" show the pull neces-

Mr. Noyes. sary to start a spike which had been driven to a fixed depth. Fine borings from the Wyoming ties were washed in running water for 48 hours, then washed in distilled water and analyzed for zinc chloride. Though they contained 20.8 oz. of zinc chloride per cubic foot before washing they were found to contain none after this treatment.

In the summer of 1896, in order to determine whether the Burnettized or Wellhouse ties retained the more zinc chloride, five ties, which had been treated by the two processes, and which had been in the ground for 6 years, were taken up, and 6-in. blocks cut from each end and from the middle of each tie, making thirty blocks in all. Analyses of ash, as made by Robert W. Hunt & Co., Chicago, showed the average of ten end blocks of the Burnettized ties to contain 0.522% of zinc chloride.

The average of ten end blocks by the Wellhouse process	0.674	per cent.
The average of five middle blocks by the Burnettizing process	0.496	"
The average of five middle blocks by the Wellhouse process	0.525	"
The average of the entire fifteen Burnettized blocks	0.513	"
The average of the entire fifteen Wellhouse blocks	0.624	"

The general conditions as to drainage, soil, traffic, etc., were the same in both cases.

While this test showed more zinc chloride retained in the ties treated by the Wellhouse process, yet there is one point which has never been touched upon, *i. e.*, the organic decomposition of the glue when not fixed by the tannic acid. This is a very important point, and should be a strong argument in favor of the three solutions as now used by the Chicago Tie Preserving Company.

The fact that it takes a great deal longer for the Wellhouse ties to dry after treatment, proves that the treatment does, to a certain extent, prevent the passage of moisture into the wood.

Mr. Wallace. JOHN FINDLEY WALLACE, M. Am. Soc. C. E. (by letter).—This paper discusses a question which is becoming yearly more and more important to the railroad companies of the United States. The annual increase in the amount of ties used for renewals and the steady diminution of the timber supply are gradually attracting the attention of railroad owners and managers to the tie question.

There seems to be little doubt that, from now on, more and more attention will have to be given to preservation methods, but this is only a step toward the solution of the problem, which must undoubtedly come in the use of some substitute for the wooden tie, and which, it would seem, must eventually compel the use of a metallic tie.

Mr. Wallace. An investigation which the writer has just completed shows that the average life of the untreated white oak tie in northern Iowa is 11½ years, in Illinois 10 years, and in Kentucky and Tennessee and the high ground in Mississippi 7½ years. These figures apply to winter-cut white oak ties grown on the high lands of Kentucky, Tennessee and Mississippi.

Black and red cypress ties, used in the low lands of Mississippi and Louisiana, have an average life of 10 years, and this life can be increased several years by the use of tie-plates, as these ties wear out before they decay.

These figures are taken from the actual records of ties used during the 10 years ending 1898, and the writer considers them reliable for the general territory of which the several districts mentioned form a part.

One difficulty met by railroad managers, in considering tie-preservation methods, is the want of accurate and reliable information as to the actual increase in life due to the various processes of treatment applied to the different kinds of material. Generally, the close-grained woods, similar to white oak, are not susceptible of economical treatment. Generally speaking, the woods which absorb a sufficient amount of the preserving material are coarse of grain, and it is usually found necessary to use tie-plates with them, at an additional expense of 10 to 15 cents per tie, in order to get the full benefit of the preserving process and prevent the tie from wearing out before it decays.

When new processes are brought before railroad managers, actual facts are necessary for the passing of proper judgment on what is the best and most economical thing to do, under the circumstances. It is very difficult to prevail on railroad managers to enter into any line of expenditure which is more or less experimental. Many railroad managers have given more or less general attention to the question of treated ties, but have, so far, not felt justified in taking practical steps toward the general use of any of the existing processes, on account of the expense and uncertainty as to results, although there is little question but that the necessities of the near future will force action in this direction.

Mr. Tratman. E. E. Russell Tratman, Assoc. M. Am. Soc. C. E. (by letter).— One of the most important points of this paper is the very forcible way in which it shows that no reliable records exist or are kept in the United States as to the life of railway ties, from which averages of life and cost of different kinds of timber can be computed. Without such records, the calculations and estimates of comparative durability and economy of different ties and different preservative processes, are really little more than guess-work (except for individual roads), as there is no real foundation upon which to base any comparisons. The few railways which keep useful records have generally such diverse forms and methods, that it is difficult to make comparisons between them.

Mr. Tratman. The ties are a very important consideration, in their aggregate cost, the labor of renewal, the disadvantages of frequent renewals (from traffic and economic points of view), and the consumption of forest timber which these ties represent. In view of all this, it is most desirable, even at this late day, to endeavor to have some uniform system adopted by which records may be kept which shall be complete, comparable, and free from the influence of the personal equation which makes present statistics so unreliable as a basis for any general conclusions. It is, of course, difficult to get a system of this kind introduced and properly followed out, but the only way is to make a beginning of some kind, and then gradually develop it on lines carefully thought out.

It seems to the writer, that the keeping of these records upon some uniform and carefully formulated system, is a duty that might be properly imposed upon the division roadmasters, or officers of similar position. The section foremen should be required to keep very careful record of the number and cause of tie renewals (decay or rail-cutting). The roadmasters should then, from this information and their own knowledge and observation, prepare the broader records. Some means of supervision should also be devised, to ensure that the inspection and renewal of ties and the keeping of the records are done carefully and not in a mere hap-hazard or perfunctory manner.

The following list shows some of the items which should be included, and Table No. 14 is a sample of the suggested form of record. With such complete and uniform records from a number of railways for a term of years, and with the records of the operations of preservative processes and their cost, some broader and more reliable information could be compiled than is possible with existing statistics. This information would undoubtedly lead to greater care in the use of ties.

1. Miles of single main track on the division.
2. Approximate tonnage carried over the division during the year.
3. Kinds of timber used and the percentage of each.
4. Number of ties per mile (according to the standard spacing or standard number per rail length).
5. Preservative treatment of the ties.
6. Number of ties of each kind renewed.
7. Cost of ties of each kind renewed.
8. Date when ties removed were laid.
9. Place where ties of each kind were obtained.
10. Tie-renewals per mile of track.
11. Kind of ballast in which ties were laid.
12. Weight of rail.
13. Are tie-plates used?
14. General condition of track; including condition of rails, and road bed, surface, line, etc.

TABLE No. 14.—TIE RECORD, SMITHVILLE DIVISION, A. B. & C. RY. Mr. Tratman.

1	50 miles.		
2	.....tons.		
3	Oak, 50%.	Pine, 25%.	Hemlock, 25%.
4	2 464.	2 816.	2 816.
5	None.	10% zinc chloride. 90% none.	10% creosote. 10% zinc chloride. 80% none.
6	5 000.	3 125.	3 750.
7	55 cts.	50 cts.	20 cts.
8	2 000 in 18..... 3 000 in 18	2 000 in 18..... 1 125 in 18.....	3 000 in 18..... 1 750 in 18.....
9	Pennsylvania.	Georgia.	Pennsylvania.
10	200.	250.	300.
11	Stone.	Screened gravel.	Common gravel.
12	80 lbs.	60 and 70 lbs.	60 and 70 lbs.
13	No.	At joints.	On all ties.
14	Good.	Good.	Rails worn, and surface poor.

C. STANLEY CHURTON, Esq. (by letter).—On reading Mr. Curtis' able and exhaustive paper one is struck by the extremely short life of the ties. This, however, is partly explained when he states that "they perish by the mechanical destruction of the fibers under the rail," and also by the cutting out of the fibers in the process of respiking. Further on it is shown that ties can be protected by plugging the spike holes, and the writer would suggest that before insertion the plugs be dipped, either in liquid creosote, or a solution of chloride of zinc, or sulphate of copper. Mr. Churton.

The whole question of preserving timber by chloride of zinc seems hopelessly mixed. For instance, Mr. Curtis, in remarking on progress since 1885, writes: "Three plants treating timber with zinc chloride were in operation in the United States, each working with a different process," and further alludes to "the method adopted to prevent the impairment of the preservative treatment by the washing out of the zinc salt, which is quite soluble in water."

The paper does not state how one process differed from the others, but the writer thinks that Mr. Curtis is wrong in his statement concerning the washing out of zinc salt. The fact is—and it is an important fact, and one not to be forgotten—that chloride of zinc acts on vegetable fiber the same as iron acts on cotton or linen, forming what is known as iron-mould. The cotton can take up only a certain quantity of iron, but this becomes incorporated with it, and no amount of washing or boiling can take it out; there is a chemical combination between the iron and the linen. An excess of iron would rot and destroy the linen, and the excess which could not be combined with the linen could be washed away.

The fiber of the wood can enter into combination with the zinc up to a certain amount, but more than that would be worse than useless,

Mr. Churton. in fact, would actually defeat its own object and hinder rather than assist the longevity of the timber.

Again, chloride of zinc attracts water from the atmosphere, therefore an excess of chloride would keep the ties perpetually wet; in fact they would never become perfectly dry; consequently, decomposition of the fiber under the rail would be hastened. It is admitted on page 324, that on the Southern Pacific Railroad, the quantity of chloride used was too great.

In some parts of Mr. Curtis' paper, the process is described as being performed under pressure, at others in a "vat," when the solution was raised to a great heat, 250° to 300°. The writer's opinion is that the life of the wood is in the sap; destroy the sap and the life is destroyed. The best way to preserve timber for railway use is to let it be well seasoned before being placed under pressure. The actual drying, under favorable circumstances, does not take very long after 10 lbs. of solution of zinc chloride of 1.025 specific gravity has been forced into it; when dry it is harder, denser and more durable. The use of the word "vat" gives one the impression that in some places ties have been preserved by being macerated in a hot solution of zinc chloride; and that great heat has been used. The timber has, in fact, been boiled in a preservative solution. The object of applying heat—which is not absolutely necessary when timber is treated under pressure—is to expand the pores and to hasten the absorption of the preservative, and the application should be continued only as long as is necessary to absorb the quantity of solution required. To destroy the sap by excessive heat, in fact, by boiling it out, is, in the writer's opinion, a positive mistake.

It cannot be too strongly insisted upon that many theorists, faddists and experimentalists have, from time to time, invented processes for the preservation of timber, which have only had the effect of destroying its vitality.

About twenty-five years ago a process unknown to the writer was much advocated, but after a little time the wood, some specimens of which were shown ten years ago, broke like carrots. Timber, like wine, requires careful and skilful handling, and those whose duty it is to treat it with chemicals should understand thoroughly the nature of the chemicals used.

The late Sir William Burnett, the inventor of Burnettizing, was a medical director in the navy, and was cognizant of the therapeutical effects of chloride of zinc on vegetable fiber. His directions were that one part of liquid chloride of zinc having a specific gravity of 1.600 should be mixed with 40 parts of water, and experience has proved that this is the best strength for treating timber, and most conducive to its longevity.

Mr. VAN VRYBERGHE DE CONINGH* (by letter).—On the Dutch State Railroad wooden ties have been used exclusively since 1889, as steel ties did not give satisfaction. Baltic pine has been used on tangents and curves of greater radius than 1 000 ms., and Dutch oak or beech for curves of less radius and for switches. Dutch oak is preferred to Baltic oak because having grown more slowly it is consequently tougher, though less showy. Up to the present time no difference has been observed between inland and foreign beech. The ties are from 2.60 to 2.70 ms. in length. Their cross-section is as shown in Fig. 1.† Mr. de Coningh.

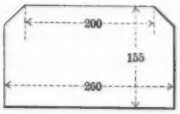

FIG 1.

The rails are of the T-type, weighing from 33.7 to 40 kgr. per meter, and are not fixed directly on the tie, but upon steel plates (shown in Fig. 2), and these, at the same time, give the desired inclination to the track. The length of these plates is 200 mm. The rail and tie-plate are fixed by spikes.

Formerly the ties were planed only at the places to be occupied by the plates, by making incisions with a saw and planing between, but these incisions caused the infiltration of rain water, and at present the whole upper surface of the tie is planed.

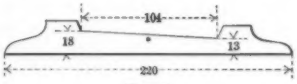

FIG. 2.

No preservative process is applied to oak ties. Pine ties are preserved by the modified Rütgers process, and beech ties with tar-oil (creosote). In the future, when the installations have been modified, the Rütgers process will also be applied to the oak ties.

All timber is cut in the winter, and great care is taken to have the ties thoroughly air-dried before they are treated, because, in that condition, the wood absorbs the preserving liquids more readily.

As navigation is closed by the ice during winter and spring, the Baltic pine is shipped to the Netherlands between June and December, and is, therefore, generally piled up in the Netherlands during one winter. Only in exceptional cases, and when there is great need for it, lumber shipped in early summer is put through the process in the fall.

Beech shipped in the spring is used in the summer. It is easily impregnated and is then very durable, but if it is not impregnated it decays very soon. Therefore, great care must be taken with it before it is impregnated, for, if it is piled up carelessly, it decays readily.

The modification of the ordinary Rütgers process concerns only the composition of the impregnating liquid, which is 5° Beaumé (4% Zn Cl^2) instead of 3° Beaumé (2% Zn Cl^2) as ordinarily used. To 30 kgrs. of the mixture (the dose for one pine tie) is added 5 kgrs. of tar-oil, instead of 2 kgrs.

* *Ingenieur der Staatsspoorwegen*, Utrecht, Holland.

† The dimensions on Figs. 1 and 2 are in millimeters.

Mr. de Coningh. Up to the present time experience has not shown that by augmenting the quantity of zinc chloride the fibers of the wood are attacked, or that the wood becomes brittle. Great care is taken, however, to keep the zinc chloride absolutely free of acid.

The quality of the creosote is fixed by prescription and regularly controlled. The process is wholly that of Burnett, applied by Rütgers: steaming, air-vacuum and impregnating under pressure, the time for each part of the process depending on the degree of moisture in the wood.

Until the impregnated ties are to be used in the track, great care is taken to keep them piled up close together; just contrary to the method in which they are piled before impregnating, which is very loose.

There are no statistics yet as to the life of impregnated ties.

The cost, during the last 6 years was as follows:

Pine ties.....	1.30 to 2 guilders (52 to 80 cents).
Beech "	± 2.70 guilders ($1.08).
Oak "	28 to 38 guilders per cubic meter.

In 1893 the cost per tie was as follows:

Pine.....	0.46 guilder (18½ cents).
Beech.....	0.72 " (29 ").

In these prices are included, respectively, 0.30 and 0.58 guilder (12 and 23 cents) for the liquids (the prices of these varying yearly), and 0.07 guilder (2¾ cents) for labor. The remainder makes up the expenses for engineers, coal, repairs to machinery, and supervision.

Mr. Rowe. Samuel M. Rowe, M. Am. Soc. C. E. (by letter).—These researches by Mr. Curtis certainly have much value, not, perhaps, for any definite conclusions adduced, or that can be adduced, so much as for giving a *résumé* of the question of timber preserving from the time of the report of the Committee of this Society in 1885 to the present time. That this article is resulting in an awakening to the importance of this matter seems to justify its preparation and the great amount of labor and care required, and it is to be hoped that something more than thanks will be accorded.

The pressing needs of the day for cross-ties to supply the waste on existing railroads and for new lines has called attention sharply to the necessity of some method of preventing the rapid depletion of the available stock of timber, particularly as few American railroads are yet prepared to resort to metal ties.

The discussion of this matter, both in this case and generally, is somewhat confusing, but probably pertinent and worthy of consideration. To extricate ourselves from this, however, and to place ourselves on something like solid ground, we are inclined to fall back on experience and give some of the conclusions derived therefrom.

Mr. Rowe.

It came into the province of the writer in 1885, to be placed in charge of the works then just completed at Las Vegas, N. Mex., a position in which it was imperative to make a close study of the philosophy, the practical workings, the methods used, the nature of the chemicals, as well as a thorough analysis of the results attained. The zinc-tannin or Wellhouse patent process was to be used, and in this study the aid of O. Chanute, M. Am. Soc. C. E., and the late Joseph P. Card, Assoc. Am. Soc. C. E., was availed of; they being owners of the then existing patents on the process. It is unnecessary to say that the conclusions there reached were and are still of much value, no occasion for revision to any extent having arisen.

It is a pleasure to read the contribution of Mr. Noyes, in reference to these works, and it is very desirable that more such men enter the field to add to the number of careful observers.

It is not deemed necessary or desirable to go deeply into this discussion at the present time, and the writer will confine his remarks to a general survey of the practical points of the situation and to the importance of educating practical operators, of whom there are too few.

We should not place particular stress on the process used, whether it be the Burnett, the zinc-tannin or the creosote process, the appliances and methods being quite similar, but on correct and efficacious methods, the main point being to get the absorption of a proper amount of chemicals, or rather to prepare the timber for it. To do this, a thorough knowledge of the absorptive qualities of the timber to be treated, as to density, dryness, etc., must be had, after which judgment and discretion, with some degree of practical experience, will be the best guides.

In regard to the question of securing any desired degree of absorption, it depends on the density of the timber; but as to the effectiveness of the process used (steaming or the vacuum), there is little question. By natural absorption, that is, by soaking or immersing in water, would require, under the most favorable circumstances, some thirty days to absorb as much as will be injected by this method in a few hours (five or six altogether).

It should be remembered, too, that the amount of chemicals, or antiseptics, has not all to do with the results, neither can a superabundance of the chemical be relied upon to make amends for lack of judgment in respect to other parts of the treatment. The overplus above that which long experience and trial in the track has shown to be necessary is worse than money thrown away. The saying in the "Hoosier Schoolmaster," "While yer gittin git a plenty," will hardly hold in this case.

The question of choosing open-grained timber is to some extent misleading, as the writer's observations for the last 15 years lead him

Mr. Rowe. to believe that the expression "the better the timber, the better the tie," is in the main true, the fact remaining that many of the timbers now deemed worthless for this purpose, may be made lasting and serviceable.

The mention of small ties, 6 x 8 ins., deserves notice. A sawed tie less than 7 by 9 ins. can on no rational grounds be defended.

The degree of drying which a tie should have should be sufficient to relieve the wood of at least half its water; the time required to do this depending on climate, moisture and other conditions which vary in different parts of the country. There may be exceptions as to this with timbers which have not yet come under the writer's notice.

If the writer were permitted, he would say to the railroad manager, that in many cases such a plant, equipped and operated, would prove of as much advantage as a repair shop, and should have the same attention and care; the manager of the works being educated in this particular line and equally as well paid as the master-mechanic of his repair shop. No man can be prepared for this without close contact with the practical part of the work and a close study of its operation.

As an example of this, one of the largest railroad systems in the United States, put aside all theories and speculations as to particular methods and took the tangible results shown on the financial sheets of cost of maintenance, viz., a reduction of renewals from over 20% in 1885, to less than 5% in 1897-98.

Mr. Eayrs. N. W. Eayrs, M. Am. Soc. C. E. (by letter).—The author has presented a deal of valuable information on the subject of preservation of railroad ties, but it is to be regretted that the paper was not extended to include ties and timber used in bridges and viaducts. The cost of renewing ties on such structures and under traffic is very much greater than that of tie renewals on ballast, and every year added to the life of such ties is more valuable than in the case of common ties.

The writer's experience in recent years has been chiefly in the maintenance of bridges, viaducts and elevated structures, and he has been surprised to find that so little effort has been made to protect bridge ties and floors from the action of the weather. For a number of years past it has been the writer's practice to paint bridge ties, and the result has been so satisfactory that he is inclined to doubt the advisability of treating such ties by any other preservative process. One great objection to using the ordinary processes for preserving such timber is, that, as universally admitted, timber should not be cut after treatment; it was suggested to the writer by the management of one preserving works that the ties should even be bored for spikes before treatment. The expense of such rehandling, and the extra freight charges, would be prohibitive.

Mr. Eayrs.

The writer's experience on the St. Louis Bridge is an instance of the value of painting ties. The railway floor of this bridge was changed to a tie floor in 1888; the ties used were 7 x 7-in., long-leaf yellow pine, carefully selected. All daps were painted before the ties were placed, and also all surfaces where wood came in contact with wood. After the floor was finished the ties were given two coats of red oxide of iron and linseed oil. These ties are in perfectly sound condition to-day. Unfortunately, tie-plates were not used when the ties were first laid, and it is now necessary to renew them on account of "spike killing" and wear; otherwise the ties would be good for 5 years longer, if not more.

In 1897, the writer renewed the entire floor of the elevated portion of the St. Louis Merchants Bridge Terminal Railway. This floor was laid in 1891 with oak ties, unpainted and untreated. Six years afterward more than 50% of the ties were so badly decayed that nothing was left but a shell. The traffic over this structure had been very light up to 1896, and, consequently, the ties had suffered no mechanical injury. The timber used in relaying was long-leaf yellow pine, and was painted with one coat of mineral paint after framing, and one coat after being placed in the track. The cost of painting the ties, two coats, averaged 11¾ cents per tie. Tie-plates were used on this structure, and, judging from the experience on the St. Louis Bridge, these ties ought to last 15 years. About 75 ties were treated by dipping into a bath of hot Woodiline, and about 150 others were painted with Woodiline applied hot. The dipped ties were allowed to remain in the bath ten minutes; the amount absorbed was 22½ galls. per 1 000 ft. B. M., or about 1½ galls. per tie. The cost of the work was 52 cents per tie for material, and about 1¾ cents per tie for labor in handling, exclusive of the cost of the tank, steam connection and fuel.

Taking into consideration the cost of the process, the uncertainty of getting the proper amount of preservative in the timber, and the necessity of treating after the framing has been done, it is the writer's opinion that for bridge ties there is very little more economy in any of the preserving processes now in use than in painting.

Mr. Selby.

O. E. SELBY, Jun. Am. Soc. C. E. (by letter).—Table No. 15 and the diagram, Fig. 3, were prepared by the writer during an investigation of the question of timber preservation for the railroad system with which he is connected, for the purpose of arriving at a rational and ready means of comparing the economy of different methods of preservation.

The diagram, omitting the four-sided figures lettered *A*, *B*, *C*, etc., is plotted from Table No. 1, page 195, of Bulletin No. 9, United States Department of Agriculture, Division of Forestry. The abscissas represent the cost in cents of each renewal, and the diagonal lines represent the intervals between renewals. The ordinates show the annual

TABLE No. 15.

	Kind of Tie and Treatment.	Cost of.			Total cost in track.	Probable life. Years.	Annual charge. Cents.	Life Necessary to Equal White Oak Tie.	
		Tie delivered.	Treatment.	Putting in track.				At 38c.	At 50c.
A....	First quality white oak, untreated. Present prices...	35 to 38	.....	12 to 15	47 to 53	8 to 10	6.1 to 8.2	.....	.....
B....	" " " " " Future " ...	50 " 55	.....	"	62 " 70	8 " 10	8.0 " 10.8	.....	.....
C....	Inferior oaks, untreated.....	30 " 34	.....	"	42 " 49	4 " 5	9.7 " 13.8	.....	.....
D....	" " Burnettized.....	30 " 34	16 to 20	"	58 " 69	10 " 14	5.9 " 8.9	$11\frac{1}{2}$	9
E....	Hemlock, gum, etc., untreated.....	28 " 32	.....	"	40 " 47	3 " 4	11.3 " 16.7	.....	.....
F....	" " " Burnettized.....	28 " 32	16 to 20	"	56 " 67	9 " 12	6.3 " 9.4	11	$8\frac{1}{2}$
G....	" " " " and tie-plates.....	28 " 32	36 " 40	"	76 " 87	11 " 14	7.7 " 10.5	$16\frac{1}{2}$	12
H....	Beech, untreated.....	30 " 32	.....	"	42 " 47	3 " 4	11.8 " 16.7	.....	.....
J....	" Burnettized.....	30 " 32	16 to 20	"	58 " 67	12 " 15	5.6 " 7.5	$11\frac{1}{2}$	9
K....	" minimum life, Burnettized.....	30 " 32	16 " 20	"	58 " 67	9 " 10	7.5 " 9.4	.....	.....
L....	" " and tie-plates.....	30 " 32	36 " 40	"	78 " 87	14 " 16	7.2 " 8.8	17	12
M....	Chestnut, untreated.....	30 " 34	.....	"	42 " 49	5 " 6	8.3 " 11.3	.....	.....
N....	" " and tie-plates.....	30 " 34	20	"	62 " 69	12 " 14	6.3 " 7.7	12	9
O....	Cedar, "	35	.....	"	47 " 50	5 " 6	9.3 " 11.5	.....	.....
P....	" " and tie-plates.....	"	20	"	67 " 70	12 " 14	6.8 " 7.8	13	10
Q....	Inferior yellow pine, untreated.....	45	.....	"	57 " 60	4 " 6	11.1 " 16.9	.....	.....
R....	" " " creosoted.....	"	45	"	102 " 105	20 " 22	7.7 " 8.4	23	$17\frac{1}{2}$
S....	" " " vulcanized.....	"	23 to 30	"	80 " 90	15 " 16	7.4 " 8.7	16 to 18	12 to 13
T....	" " " " and tie-plates.....	"	43	"	100 " 103	16 " 18	8.5 " 9.5	24	17

Mr. Selby.

Mr. Selby.

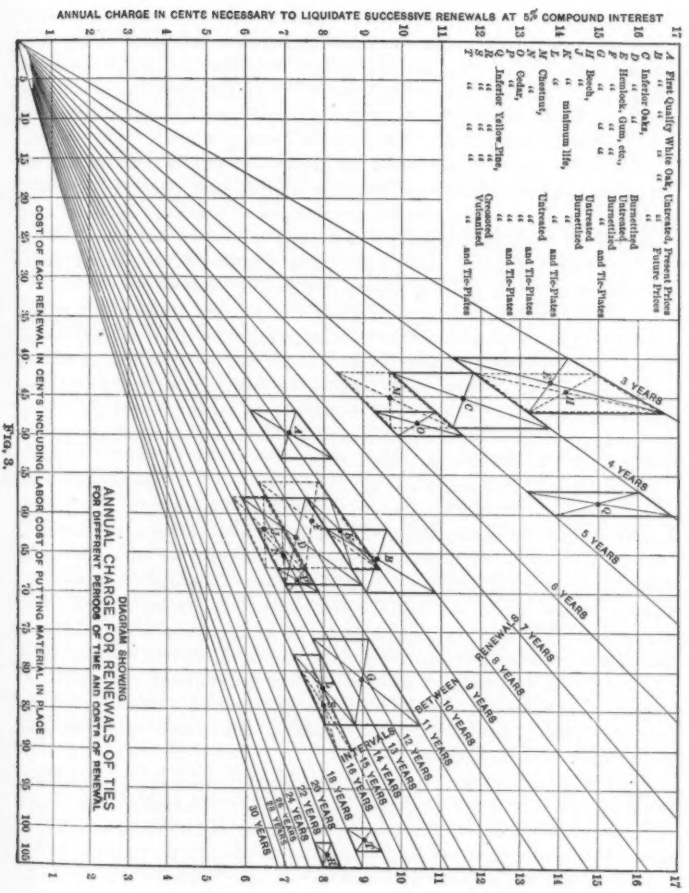

FIG. 3.

Mr. Selby. charge in cents, based on 5%, compound interest, necessary to liquidate the succeeding renewals at the intervals shown. In other words, it is the amount which it would be necessary to set aside each year and invest at 5%, compound interest, in order to equal, in the end, the cost of all renewals reckoned at the same rate of interest.

The diagram shows graphically and exactly the comparative ultimate economy of various methods involving various lengths of life and initial costs. The only approximation involved is in the assumed lengths of life and assumed costs. Comparisons can be made for structural timber by taking the costs and annual charges in dollars per 1 000 ft. B. M., instead of in cents per tie.

While it is known that most railroads can now obtain money at less than 5%, it is believed that the addition of general expenses, taxes, costs of financing, uncertainties in distribution of expenses, etc., makes a 5% basis of comparison a proper one, especially as it works to the disadvantage of the longer-lived ties and processes, as to the durability of which there is necessarily much uncertainty.

The table was prepared to include the principal kinds of ties and methods of treatment available on a large scale on the system in question. There are several species of wood, such as catalpa, sassafras, black walnut, etc., which are known to be very durable and valuable for cross-ties, but which are not available in large enough quantities to have much effect on the tie supply of a large system, and they were not included in the comparison.

The basis of comparison is the first-class tie, of white oak, burr oak or post oak, filling the present specifications of the system, costing 35 cents to 38 cents each, and lasting in the track from 8 to 10 years, under reasonably favorable conditions. In view of the increasing scarcity of such first-quality oak, and rapidly advancing prices, a comparison is also made on a basis of the probable early future cost of 50 cents each. The assumptions in the table, as to cost of ties, treatment, putting in track and probable life, are based on reports from division engineers, and information from other sources, including Mr. Curtis' paper, applicable to the middle western territory covered by the system. Limits were used rather than averages so as to show the possible range covered by each process.

The column headed "Total Cost in Track" is made up by adding together the cost of the tie delivered, the cost of treatment, if any, and the labor cost involved in removing the old tie and putting in the new one. It is important that this item of cost of putting in track be included in all comparisons, as it is certainly an expense involved in each renewal, and its omission gives an unfavorable advantage to the short-lived ties and processes. The column headed "Annual Charge" is taken from the diagram for the preceding data of total cost in track and probable life. The last two columns of the table show the length

Mr. Selby.

of life which must be realized by the different processes at the assumed costs in order to equal in economy a white oak tie, first, at present prices; second, at future prices. This was obtained from the diagram by following out the horizontal line representing the average annual charge for the oak tie to its intersection with the vertical line representing the average cost of the treated tie. The year lying nearest this intersection is the required life.

The use of metal tie-plates, with treated and untreated ties, was considered, together with other methods of preservation, and the results show it to be a most promising method with soft wood ties. The cost of tie-plates was assumed at 10 cents each, including the cost of their transportation to the site and putting them in. This may seem high for small plates, but it is likely to be realized with the advancing prices of steel.

Two assumptions were made for Burnettized beech ties, the first based on their claimed and probable life of 12 to 15 years, and the second on a life of 9 to 10 years, which seems a certain minimum, in view of experience with the process and of improvements now being tried. The range of cost of vulcanizing was made large to cover both the present cost and the future reduced cost of the process if it proves successful and works are established in the West. In view of developments in the tie market, since the table was made, the price of cedar ties was probably taken too low.

The data in the table have been plotted on the diagram, each kind of tie being represented by a four-sided figure, within the limits of which will be found the actual annual charge, the intersection of the diagonals locating the average. Those plotting nearest to the base line show the lowest annual charge, and hence the greatest economy.

The one which plots lowest is the beech Burnettized, but if its life is proven to be only 9 or 10 years it plots much higher, but is still lower than the white oak tie at 50 cents. The chestnut tie with plates, the cedar tie with plates, and the inferior oaks Burnettized, all show greater economy than the white oak tie at 38 cents delivered. All the processes of treatment plotted show greater ultimate economy than a white oak tie which costs 50 cents delivered and lasts only 8 to 10 years, indicating that the time is rapidly approaching when some form of preservation will be imperative.

On the face of the diagram the best showing is made by the Burnettizing process, and by untreated, long-lived, soft wood ties with plates.

The flat inclination of the lines representing the longer periods of years shows that the amount we are justified in spending for a tie increases rapidly with the life realized; that is, the annual charge increases more slowly in comparison with the first cost for the long-lived ties than it does for the short-lived ties.

Mr. Selby. The cost and probable life in any individual case may easily fall outside the limits plotted, but in any case it is easy to follow out the horizontal line corresponding to the cost in track and probable life of ties in use to find the life which it will be necessary to realize from a process of given cost, or the amount which it is justifiable to pay out to secure a tie of a given life.

The writer's investigation resulted in a recommendation for the purchase of a considerable number of inferior oak ties and their treatment by Burnettizing, and the purchase of a like number of cedar and chestnut ties and their use with tie-plates; the number recommended being large enough to be considered experimental on a large scale.

There is much promise in a modified Burnettizing process, now being investigated by a leading tie-preserving company, consisting of the injection of both creosote and zinc chloride. This is likely to prove durable, but may be too expensive. The writer agrees with others who have taken part in the discussion that much of the hesitancy of the managements in authorizing the use of treated ties is on account of the uncertainty which exists as to the actual life, under varying conditions, both of ties now in use and of the treated ties.

Certainty, in this direction, is only to be attained by careful records of all ties in the track, showing length of service and actual cause of removal. Such records would be of value in determining, not only the necessity for and the best processes of treatment, but in indicating the value of improvements in any given process.

Mr. Chanute. O. CHANUTE, Past-President, Am. Soc. C. E. (by letter).—This paper chances to be most timely, for its publication concurs with one of those swift advances in prices which take place when it is suddenly discovered that the supply has been overtaken by the demand. One year ago ties were selling about as cheaply as they had been for 10 years past. In Chicago, for instance, white oak ties were quoted at 45 cents and cedar ties at 36 cents, while now the price of white oak is 60 to 65 cents, and of cedar 50 cents, with talk of further advance. Railroad men, therefore, are considering now the use and treatment of the cheaper and more perishable kinds of wood, which are still abundant.

There is no longer any question in the mind of the writer that chemical treatment, applied thoroughly and skilfully, will more than double the life of the inferior woods, and make it equal or superior to that of the more durable woods laid in their natural state. All the European experience has proved this, and in spite of some failures, due to ignorance of all the conditions of success, American experience is seen to confirm that of the Europeans.

The writer drifted into this business by chance some 14 years ago. He sees now that he made some mistakes in the beginning, and had much to learn concerning the idiosyncracies of various woods, so that his experience may be of value to those who may carry on such

work hereafter. His first mistake consisted in the apprehension that strong solutions would make the ties unduly brittle, and in believing that solutions of zinc chloride of 2° Beaumé, or less, would penetrate farther into the wood than stronger and less limpid solutions. Mr. Chanute.

In 1879, Mr. B. F. Bischoff, then in charge of the tie-preserving works of the "Empress Elizabeth Railway," of Austria, read an elaborate paper before the Austrian Railroad Club, in which, after describing the then state of the art, he gave an account of some experiments which he had made, and which went to show that zinc-chloride solutions of 1.7° Beaumé could be forced into the wood further, and that they protected the ties better, than solutions of 3° Beaumé. He instanced, as proof, the results cited by Mr. Funk, in a paper which has remained a classic, concerning the life of ties treated with solutions of 2° Beaumé, and he stated that the "Empress Elizabeth Railway" had changed over from the use of zinc-chloride solutions of 3° Beaumé to those of 1.7° Beaumé. This practice, which seemed to promise some economy, was followed by many German railways, but the results were not found satisfactory. It was ascertained that these railways did not do as good work as others, which used stronger solutions, and the German specifications of 1898 and 1899 require the use of solutions of 3.5° Beaumé, and the injection of 0.50 to 0.55 lbs. of dry zinc chloride per cubic foot of wood.

In consequence of the fact that American ties get less seasoning than is usual in Germany, the writer began treating ties at Chicago in 1886 with solutions of 3.5°Beaumé, at 80° Fahr., and he has gradually increased the strength to 5° Beaumé, having in the meantime learned by experiment how to inject these strong solutions without making the tie brittle. Not one of them has broken in the track. He is now injecting two and a half times as much chloride of zinc as he did at the beginning, and has every reason to believe that the results, with ties treated since 1896, will be entirely satisfactory.

His second mistake consisted in assuming that there was no great difference in the quantity of solution absorbed by each individual tie in a run, and that they might be treated with success in the order of their arrival. Unfortunately, ties arrive in Chicago by vessels in varying condition; some have been cut longer and are better seasoned than others, while particular cargoes, or parts of cargoes, have been rafted out to the vessels, and are saturated with water. It was believed at first that these varying conditions could be overcome simply by changing the strength of the solution, from day to day, to correspond, and that satisfying results would follow. This proved to be an error, and now refractory ties are unloaded upon the ground to season; some 70 000 having been so treated in 1898, and some 120 000 in 1899. Moreover, hundreds of experiments with individual ties, made by weighing them just before and after treatment, have established the

Mr. Chanute. fact that there are surprising differences in the receptivity of various kinds of wood, and of various ties cut at the same time and from the same forest. Some will absorb three times as much as others, and, in extreme cases, when both seasoned and unseasoned ties are tested, the differences are as 8 to 1. The conclusion drawn was, that, in order to inject the minimum of zinc chloride guaranteed in every tie, it was necessary to inject on an average about three or four times this quantity, and this is now being done.

This difference between individual ties was found to be greatest with tamarack, probably in consequence of the varying amount of resin contained therein, and, after many experiments, the treatment of ties of this class was reluctantly abandoned.

Thus it is seen, that, simple as the process appears, theoretical knowledge alone is not sufficient to insure doing good work. Practical experience is required constantly, and this is acquired best with a small experimental plant, with which various methods may be tested without interfering with the regular runs.

It is unfortunate that various changes in the personnel of the maintenance-of-way departments of some of the railroads first adopting tie-preserving methods in this country should have produced discontinuity in the records, but these are sufficient, as Mr. Curtis has shown, to prove that inferior woods are made more durable than white oak, and we may expect still better results now that experience has taught us how to do the work better.

The writer is satisfied that his present practice of injecting from 0.50 to 0.55 lbs. of zinc chloride per cubic foot of wood is an improvement over his earlier methods. Also, that the injection of three separate solutions instead of two is a decided improvement. He believes the zinc-tannin process, thus applied, to be better than the zinc process alone, and that experience in regions of abundant rainfall will prove this to be a fact. Burnettizing, as we know, has been abandoned in England, while it is a success in Germany, probably in consequence of the difference in rainfall in those two countries.

In the hope of learning still more about the anomalies of various woods, and the best methods of treating them, the writer is now about to visit Europe, where far more experience has been accumulated than in America, and he regrets that the present publication of this valuable paper will prevent this discussion from containing the results of his pending tour of observation.

Mr. Curtis. WALTER W. CURTIS, M. Am. Soc. C. E. (by letter).—When the author undertook the investigation of the treatment of railroad ties, he was desirous of making it complete, if possible; and for this purpose applied for information to the manufacturers of all preserving materials, to all the treating works in this country and to all the railroads which, as far as he could ascertain, had ever experimented with

treated ties. The vulcanizing process was the only one, known to him, not investigated. Mr. Curtis.

He was favored with replies to most of his inquiries, and followed up all the avenues of investigation opened. The resulting information regarding other preservatives than zinc chloride was so slight as to be practically valueless, and he concluded to omit all mention of them.

There is no question of the superiority of creosoting over any other treatment, but it would be rather difficult to prove it by American records. On account of the cost of the treatment, most of the creosoted material has been used for other purposes than ties; and the object sought has been not so much protection from decay as from destruction by marine life.

Where creosoted ties have been used, generally no record of them has been kept, and no accurate life for them can be computed. No figures comparable, either as to accuracy or number considered, with those given in the paper for Burnettized ties on the Southern Pacific or the Atchison, Topeka and Santa Fé roads, are obtainable.

The author does not desire to be understood as condemning any of the processes now in use. He simply could not find sufficient evidence to justify him in presenting them.

It is unfortunate that it is impossible to give exact data covering all the ties treated with zinc chloride; but it seems unwise and unscientific to belittle what we have because it is not more. The material question is: Is our information sufficient to enable us to draw reasonably correct conclusions—not, is it perfect? The statement made by one gentleman, that we are no further ahead in our knowledge of the subject in 1899 than we were in 1885, in view of the records of the two roads above mentioned, omitting all others, is absurd.

Mr. Lowinson speaks of an unfavorable experience with Burnettized ties on the Erie Railroad. This statement has been the subject of the same critical examination given to all in the original investigation; and it is proven to be entirely in error. The Erie Railroad has made no experiments with Burnettized ties, except as specified in the report of the Committee of 1885, and as quoted in this paper. The author is advised by Mr. Lowinson that his statement was incorrect; due either to his misunderstanding information given him or to misinformation. To the author it seems probable that it was due to a confusion of processes.

Replying further to Mr. Lowinson's discussion, the distribution of the chloride throughout a tie is quite uniform. The analysis of a tie which had been in service for 11 years on the Union Pacific Railroad, as given on page 311, showed the same amount of the preservative at the center as at the ends of the tie. In the analyses given by Mr. Noyes, on page 352, the percentage of chloride at the center is but little smaller than at the ends. Table No. 13 shows very much more in the edges than in the center; but this is probably due to the test

Mr. Curtis. having been made soon after injection. The statement is made that the chemicals diffuse themselves throughout the timber after the treatment has ceased, and while still in solution before the water has evaporated. No analyses are at hand, however, to prove this; but there is no doubt of the uniformity of the injection.

Generally, no measures are taken to protect ties where cut or bruised after treatment. Undoubtedly, it reduces the life when ties are thus injured, but, the treatment not being a superficial one, it is perhaps not as serious as with some other treatments. Naturally, the more surfaces open to attack, the more rapid the failure.

The author does not say that the transverse crushing is a negligible quantity; in fact, he expressed himself as of the contrary opinion.

It is to be regretted that Mr. Haines has been able to find so few facts in the paper; it is only necessary, however, to call attention to his misunderstanding of Mr. Kruttschnitt's experience. The treatment of ties on the Atlantic System was begun in 1886 under his direction, and he has given it his continued attention ever since; so his statements date from that year, not from 1894, as Mr. Haines states.

The data Mr. Boggs gives for the creosoted ties on the Houston and Texas Central Railroad are valuable and tend to confirm the general opinion of the value of creosoted ties, when properly treated. It is feared, however, that it is a hopeless task to endeavor to persuade our railroad officers to spend 40 or 50 cents for treatment, however good the results may be.

Apparently, the experience with Burnettized ties, cited by Mr. Boggs, has little bearing on the value of such treatment; the material used being so poor, or the treatment so defective, as to permit physical failure rather than decay.

The notes regarding Swiss practice, as given by Mr. Wagner, are interesting; but the American public is suspicious of foreign data unless they are so complete as to permit of an independent opinion being formed. The conditions may be entirely different or the conclusions reached may be based upon an insufficient number of facts; and unless the information comes from one who has investigated the situation personally, and who is known to our railroad officers, it is doubtful if any foreign data will get much of a hearing before them.

The near future will, no doubt, give us more men like Mr. Noyes, who can speak from long-continued close contact with the question. He emphasizes one of the difficulties mentioned in the original paper, viz., the necessity for sound material. Many ties treated in the past have been dead before they were treated, and should have gone into the fire instead of the cylinders. Careful inspection by experienced men will greatly decrease this risk, however; and the rule should be to reject improper material whenever found, regardless of the number of inspectors it may have already passed.

Mr. Curtis.

The reason given by Mr. Noyes for the necessity of seasoning after treatment by the zinc-tannin process, viz., to permit the particles of artificial leather to lose their water and become hard, seems rational. There is no doubt, in the author's mind, of the necessity for this seasoning with either of the zinc-chloride processes, but it would seem especially desirable with the double treatment.

The author has just completed an experiment to demonstrate what difference in the rate of absorption there might be in timber treated in various ways. A tie was selected, cut into four pieces, each weighing exactly 31½ lbs., and numbered 1, 2, 3 and 4. No. 1 was steamed 3 hours and placed in a vacuum of 20 ins. for ½ hour. No. 2 was treated the same, and, in addition, was under 100 lbs. pressure in zinc-chloride solution for 3 hours; in other words, it was Burnettized. No. 3 was treated like No. 2, and, in addition, received the glue and tannin treatment. No. 4 was left in its original state. All pieces were then placed over the boilers, where they were subjected to slight heat only. After 19 days they were weighed again, and then all were immersed in water. The resulting absorption, after 27 hours, was 3½ lbs. for No. 1, 3½ lbs. for No. 2, 2 lbs. for No. 3, and 3 lbs. for No. 4.

No conclusive judgment can be based on one experiment, but this seems to indicate that glue and tannin are effective in decreasing the absorptive power of timber. A tie treated with these specimens, and given the full zinc-tannin treatment, weighed 163.5 lbs. before and 195.5 lbs. after treatment; and two weeks later, after exposure on the ground, part of the time in the rain, weighed 174 lbs., showing how rapidly ties lose the water of injection.

Mr. Noyes refers to 305 experimental ties treated at Las Vegas and placed in the tracks at North Topeka in 1885. In 1891, 99.3% were still in service, and only 40 showed signs of decay. Mr. Noyes says that in 1895 all those on the 4°-curve (153 in number) were taken out, principally because of wear under the rail and spike-killing. Of the 152 on the tangent, only 22 were removed, leaving 130 still in. On October 31st, 1896, 81 were still in track. In a letter to the author, dated November 17th, 1898, Mr. Dun, Chief Engineer, stated that 81 were then in track, but that they were in bad condition, and would soon have to be removed. Mr. Noyes states, also, that the average life of white oak ties at this point is but 7 years. These treated ties were the New Mexico mountain pine, having a life, untreated, of from 4 to 5 years. The treated ones at North Topeka lasted 10 years on the curve, and the average life of those on the tangent is 12 years, thus—

22	ties removed in 1895, after 10 years.....	220	years.
49	" " " 1896, " 11 "	539	"
81	" still in track, 1898, but considered worn out, after 13 years.....	1 053	"
152	" at average life of 11.92 years.....	1 812	"

Mr. Curtis. Mr. Wallace expresses very well the view which railroad operators take of all questions connected with their work, and it is a view with which the author has no disposition to find fault. To begin the use of treated ties on a large scale means either the investment of a large sum of money in a plant, or the incurring of a large liability to private works for a term of years. When it can be demonstrated, however, that good results have been secured on at least two large roads, the element of uncertainty is very largely removed. Even if the experimental ties laid at La Junta and Topeka, described on page 306, and those at North Topeka, just referred to, are rejected as being only experimental, and those on the Ft. Wayne and the Duluth and Iron Range Railroads as being too recent, there remain the records of the New Mexico Division of the Atchison, Topeka and Santa Fé Railroad, which show that during 21 months ending December 31st, 1898, 27 694 of the ties treated in 1885 (being about one-fourth of the total number treated that year) were removed from the tracks, leaving a considerable number still in. The renewals on this division of 380 miles for the 5 years, 1893 to 1897, averaged but 217 per mile per year, while with the use of untreated oak ties, a renewal rate of 350 per year would not be excessive. Then on the Southern Pacific Railroad 93% of the ties treated 8 years before were still in service. The author has recently received from Mr. Kruttschnitt data bringing the records of this road down to July 1st, 1899. In Table No. 8, the percentages of ties July 1st, 1899, remaining in track were: After 11 years, 20%; 10 years, 78%; 9 years, 85%; 8 years, 94%; 7 years, 97%, etc. In Table No. 9, the average age of ties removed from January, 1896, to July, 1899, was 8 years 6 months, instead of 7 years 11 months. In Table No. 10, the average life of ties removed during year ending July 1st, 1899, was 8 years 6 months for the Glidden District, and 9 years 7 months for San Antonio District. This shows a continued increase in the average life of ties removed.

Such results cannot be called experimental.

If Mr. Churton will re-read the paper, he will find on pages 304 and 305 descriptions of the three processes in use in 1885; that the word "vat" occurs but once and then in a quotation; and that it is not admitted that the amount of chloride on the Southern Pacific was too great, but, in the author's judgment, was less than is desirable.

The comparison of the action of zinc on wood fiber with that of iron on cotton, he will have to leave to the chemists. An excess of iron in the zinc will most certainly injure the tie, and a very small amount of it constitutes an excess. Mr. Churton's idea as to what constitutes sound timber when cut down, differs from all authorities known to the author. The sap is a very essential element to a growing tree, as blood is to a living man; but the general impression is that a tie has the same use for sap that a mummy has for blood. If Mr. Churton knows of any treating works which have treated timber successfully without the

use of heat, it would be interesting to know of it. It would probably be an improvement if it were possible. Mr. Curtis.

Mr. Rowe's remarks about a surplusage of chemicals are deserving of consideration, particularly in view of his long experience in preservative work. It is well to remember, however, that there is no evidence that too much has been injected in recent years in this country, to the detriment of the timber; there is good evidence that it does gradually leach out; and the presumption is that the only undesirable result, if any, of a heavy injection, is the extra cost of the treatment.

It certainly seems to be the part of conservatism to inject up to ½ lb. of dry chloride per cubic foot of timber, when such an absorption can be obtained. The author takes the same position in regard to the zinc-tannin process, as compared with Burnettizing, proper. The additional cost of the glue and tannin is justified in view of the probable additional life of the ties. It will be time to abandon it when the Southern Pacific Railroad has demonstrated that it can get as long life from its Burnettized ties in Oregon and Northern California as others get from the zinc-tannin process in similar climates; or when some superior treatment is offered.

Replying to Mr. Eayrs, insufficient data was obtainable to cover bridge ties and timbers. So far as the author knows, no works, except those of the Atchison, Topeka and Santa Fé Railroad at Las Vegas, are treating such material with zinc chloride. Mr. Noyes writes that he is treating all their piling and bridge timbers, excepting the stringers, which are Oregon fir, and very durable in their natural condition; the piling being used both in wet and dry situations. The results are reported as satisfactory. There is an idea prevalent in the minds of some who are familiar with the treatment, that it is not adapted to timber which is exposed, as are bridge ties. It is supposed that the zinc may be more readily washed out under these conditions; but no evidence to support the theory is produced; and in the author's judgment it is based on a fallacy. So far as the moisture is concerned, he believes that less damage will be done to bridge ties than to track ties. He would not advise the use of Burnettized timber for stringers but believes it is well adapted for use in all other parts of viaducts or bridge floors. Its value for piles exposed to water in streams remains to be demonstrated.

Mr. Eayrs is in error as to the expense of dapping and boring ties. In connection with treatment, the ties can have the rail seat dressed and the spike holes bored for about 3 cents per tie. This would, undoubtedly, add materially to the life of the ties, and is something which will be done in future years, no doubt. The works at Las Vegas had a dapping machine in service some years ago, but its use was discontinued, apparently, because it was considered unwise to be too progressive.

Painting bridge ties will undoubtedly increase their life, provided the timber is thoroughly dry when painted. Otherwise it would seem

Mr. Curtis. inimical rather than beneficial. If the ties have been left too long unpainted it seems doubtful as to its advantage. If the injection of chemicals entirely throughout a stick is unable to prevent its destruction if decay has begun, what is the probable chance of doing so by the application of two or three coats of paint to its surface? It would be dangerous to draw any general conclusions as to the effect of paint on ties from the success with the long-leaf yellow pine at St. Louis. Poorer or different woods would probably show very much less satisfactory results.

Mr. Selby has worked out a very convenient and complete table of the relative costs of various ties. Where first-class oak ties can be purchased for only about 10 cents more than it is necessary to pay for a tie suitable for treatment, there is no inducement to adopt the latter, unless a very short life is being realized from the oaks, as on the Atchison, Topeka and Santa Fé Railroad, or where the climatic conditions are such as to justify the very cheap work of the Southern Pacific. The author depends more on the advancing prices of the oak and cedar ties than on economies demonstrated by means of calculations of compound-interest costs, to create a demand for treatment works; not because the latter are necessarily deceptive, but out of deference to the conservatism of officials.

The author desires to make but one criticism on Mr. Chanute's discussion, and that is, in reference to the use of tamarack. Mr. Chanute found it impossible to get as uniform absorption of the chemicals with this material as with hemlock. Of course, the object of treatment is not, primarily, to furnish a market for the zinc product of the country, but to increase the average life of all the ties treated. Before the use of treated tamarack ties is condemned, it is desirable to show that the average life secured is not satisfactory. This has not been done, and, at present, cannot be done; in fact, the evidence is rather to the contrary. Mr. Chanute being the owner and operator of private works, naturally desires to treat those timbers which will take the treatment readily, and does not feel called upon to risk his reputation to demonstrate that even a refractory material will give good average results. The author believes that tamarack can be treated satisfactorily and profitably.

Since this paper was presented to the Society three of our large railroads have started the construction of treating works. The Chicago, Burlington and Quincy Railroad has a two-cylinder plant under construction in the Black Hills of South Dakota; the Great Northern Railroad a three-cylinder plant, and the Mexican Central Railroad a three-cylinder plant in Mexico. Mr. A. A. Robinson, president of the Mexican Central Railroad, was the General Manager and Chief Engineer of the Atchison, Topeka and Santa Fé Railroad when the Las Vegas plant was built in 1885, and it was due to him that the road adopted the treatment. The construction of the proposed plant in Mexico is the best evidence of his satisfaction with the treatment.